1

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Dr. R.L. Eshleman
Vibration Institute
Suite 206, 101 West 55th Street
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Code 5804, Naval Research Laboratory
Washington, D.C. 20375-5000
(202) 767-2220

Dr. J. Gordan Showalter
Acting Director

Rudolph H. Volin

Elizabeth A. McLaughlin

Mary K. Gobbett

SVIC NOTES

Some Thoughts on Fragility

Very little has been published about the concept of fragility in the open literature, the concept of fragility is not widely used, and its true meaning may not be widely understood. This is a good opportunity to briefly explain the concept of fragility, to discuss some of the difficulties associated with establishing the fragility of equipment, and to discuss some of the uses of fragility data.

The fragility of equipment refers to the maximum load it can withstand before a failure occurs, regardless of the failure mode, e.g., malfunction, irreversible loss of performance, or structural damage. To establish the true fragility of equipment, it must be tested at potentially destructive loads, and depending on the potential failure mode, several samples may have to be tested to account for the variations in tolerances, materials properties, and manufacturing processes. For these reasons, and because many items of equipment are often extremely expensive, fragility tests are expensive, so fragility tests are rarely conducted; this is why true fragility data for equipment are scarce.

Another reason why fragility tests are not conducted is fragility is not a simple concept. The type of fragility must be defined, e.g., shock fragility or vibration fragility. The potential failure modes and the relevant failure criteria for the equipment must be defined, and the failure points must be known. Deriving the inputs to characterize the shock or the vibration fragility is difficult because several types of inputs can be used. Further, the damage potential of a given level of input to an item of equipment depends on a widely variable combination of parameters. Other potentially complicating factors include the interaction between the test article and the test equipment, nonlinear behavior of the equipment, and the transfer functions between the input points to the equipment and the mounting points of critical components.

In spite of the expense and the difficulties of obtaining fragility data for equipment there may be times when such data are essential. Certain items of equipment must operate properly in, or survive their operating environments to ensure system safety. If it is known that the equipment will not survive its operating environment, then fragility data are necessary to design an isolation system to protect it. One author has suggested fragility data might identify minor design changes that could be made to upgrade the capability of the equipment to withstand its operating environment (1). Fragility data may still be useful even if the equipment can pass its qualification test. Quite often the operating environment is more severe than predicted; if the equipment's fragility is known it may reduce the need to reanalyze, requalify, or redesign the equipment. Although not as important as system safety, the same reasoning applies to equipment that is used in an environment that differs from the one for which it was originally designed (2). Other uses for fragility data have been suggested, and some of them may have been based on misconceptions of the meaning of fragility. Once one understands the true concept of fragility then it is possible to appreciate the uses and the limitations of fragility data for equipment.

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RHV

EDITORS RATTLE SPACE

At the present time we are in the process of modifying some of the sections of the **Shock and Vibration Digest** in an attempt to provide a better product to the reader.

The **DIGEST** is a secondary technical journal dedicated to the task of organization, refinement, and distillation of the literature published in the public domain. The **DIGEST** is designed to provide the reader with an efficient and organized overview of the literature in a minimum amount of time. To more effectively provide this service we feel that some minor changes need to be made in the **DIGEST.**

The first goal is to provide more literature reviews in organized serial form. This would provide more critical evaluation of new literature. The abstract section, which provides an objective view of the literature, will be distilled to avoid entries due to republication, trivial contributions, and marginal technical areas. The titles of papers published from symposia, conferences, and meetings will be regularly published.

We would like to hear your comments on the **DIGEST** by letter or on the reader survey form provided in the December, 1985 issue. We are especially interested in your technical interests. If you wish to participate in the literature review process, please call or write to me.

R.L.E.

FINITE ELEMENT ANALYSIS OF VIBRATION OF TAPERED BEAMS

A.K. Gupta*

Abstract. Various approaches for finite element analysis of vibration of tapered beams and frames composed of tapered beams are discussed. Applicability, accuracy, and computational efficiency of the stiffness and consistent mass matrices for tapered beam elements, derived by various authors are reviewed.

Tapered member framing has been utilized in a variety of building frames of steel, concrete, and timber to achieve a better distribution of strength and weight and sometimes to satisfy architectural and functional requirements. The use of tapered structural elements with tapered depths or widths was first proposed by Amerikian [1] for reasons of economy. Tapered members are adaptable to bolted and conventional poured-in-place concrete construction and, more commonly, to welded steel and precast concrete construction. These applications can result in large reductions in the weight of the framing material as well as appreciable savings in construction costs.

Analysis and design of frames with tapered members to resist wind gusts, earthquakes, or forced vibration requires knowledge of natural frequencies and mode shapes of vibration. There is an ample bibliography on the subject of vibration of beams of variable cross section [2-3]. Earlier solutions for vibration of tapered beams were limited to certain cross sectional shapes, taper, and end condition and were obtained in terms of Bessel Functions [4].

Simple structures such as beams for which exact solution can be developed are valuable for evaluation purposes; application of classical methods for exact solutions to more complex configurations such as frames with tapered members is impractical. Approximate analytic methods and numerical approaches such as finite difference [5] and finite element methods are being increasingly applied to vibration analysis. A favorite method for solving vibration problems of tapered beams or frames made of tapered beams is the finite element method. This article reviews the finite element idealization of tapered beams and members of frameworks by uniform or tapered elements for vibration analysis purposes. Stiffness and consistent mass matrices for tapered beam elements, developed by various authors are also presented. Applicability, accuracy, and computational efficiency of flexural vibration analysis of beams and frames composed of tapered members, using uniform and tapered beam elements, are discussed.

UNIFORM ELEMENT STIFFNESS AND MASS MATRIX APPROACH

The finite element method has been applied successfully to frameworks composed of prismatic members. When treating tapered beams by the finite element method, the simplest and most common approach has been to consider the beam as approximately equivalent to a number of prismatic elements. The sectional dimensions of each element are obtained by averaging those at the two ends of the element [6]. Values for the moment of inertia and area of cross section of each element are calculated at the center of the element [7]. Stiffness and consistent mass matrices for a uniform beam element with two degrees of freedom at each end, one translation and one rotation, are available [8].

A method for vibration analysis of beams and frameworks with uniform or nonuniform members has been published [9,10]. The structural members are divided into multiple segments in which the elastic properties are considered uniform; masses are lumped at the nodes. It is expected that the errors in this procedure would increase rapidly as variation of the moment of inertia over the segmented length increased. Results of vibration analysis for some tapered beams using uniform beam element stiffness and consistent mass matrices have been given [2,7]. These results were compared with those obtained using a derived stiffness and consistent mass matrices for tapered beam elements. A marked improvement in the results was noted when tapered beam elements were used instead of uniform beam elements.

Although the idealization of tapered beams by uniform elements for vibration analysis leads to a convergence to the correct solution as the number of prismatic elements is increased, computer time is costly and data preparation is

* Gupta Engineers, 35690 Gleason Lane, Fremont, CA 94536

tedious. Therefore, efforts have been made within the last two decades to derive stiffness and consistent mass matrices for beam elements of linear and nonlinear tapers and cross sectional shapes.

TAPERED ELEMENT STIFFNESS AND LUMPED MASS MATRIX APPROACH

It can be shown that the accuracy of results of static analyses do not depend on subdivisions when stiffness matrices derived from exact displacement functions for tapered beams are used in the analysis [11]. Similarly, efforts involved in computing the dynamic response of tapered beams to arbitrary forcing functions can be minimized if stiffness and mass matrices of good accuracy can be used with the fewest number of degrees of freedom.

The first stiffness matrix for a nonuniform beam element appears to have been derived by Lindberg [12]. The method presented for deriving a dynamic stiffness matrix [8] for any nonuniform beam uses a cubic displacement function. A dynamic stiffness matrix for a linearly tapered beam element of some cross-sectional shape is given in explicit form. Mass lumping was used by Lindberg for vibration analysis of a linearly tapered cantilever beam. Using the same approach, Thomas and Documaci [13] introduced two tapered beam elements for vibration analysis. These elements were derived using a quintic polynomial displacement function. The results obtained using these elements were compared with those obtained from the dynamic stiffness matrix derived by Lindberg [12].

Avakian and Beskos [14] analyzed a nonuniform cantilever beam by dividing it into a number of uniform beam elements for which the dynamic stiffness matrix was known [8]. Masses were lumped at the middle of the elements. The results thus obtained were compared with those obtained using static stiffness matrix for uniform elements and those given by Gallagher and Lee [7].

Some investigators [11,15-18] have developed static stiffness matrices for tapered beam elements. Newmark's numerical method of successive approximation was used to develop a stiffness matrix for a nonuniform beam-column element [15]. Just [11,16] derived a stiffness matrix by first obtaining displacement functions in terms of beam geometry. The accuracy of the stiffness matrix was verified by analyzing two propped cantilevers of tapering I-section. A procedure for easily determining a stiffness matrix for major axis flexure of a doubly symmetric I-section member with linearly varying depth has been given [17]. The web was neglected. The bending stiffness matrix for a member of varying section was based on the assumption that the displacement function for a uniform beam can be used as an approximation to the correct displacement function for a tapered beam [18]. This leads to simplicity in the computation and provides sufficient accuracy for most purposes.

TAPERED ELEMENT STIFFNESS AND CONSISTENT - MASS MATRIX APPROACH

When mass matrix coefficients are computed using the same interpolation functions used to calculate stiffness coefficients, the result is called a consistent mass matrix. A lumped mass matrix is diagonal and leads to a simple technique of formulation and solution; however, the computed natural mode frequencies and shapes may differ greatly from the solution to the exact problem.

Archer [19] investigated a formulation for consistent mass matrices for finite elements. He provided stiffness, consistent mass, and rotary inertia matrices for Timoshenko beam element with linearly varying stiffness and mass [20]. These matrices were derived using displacement functions for a prismatic Timoshenko beam element.

Gallagher and Lee [7] derived flexural and geometric stiffness and consistent mass matrices for a general nonuniform beam-column element; they used a cubic displacement function. Moment of inertia and area of cross section of the element were prescribed by arbitrary powers of the axial coordinate. Numerical results were obtained for a cantilever tapered beam and compared with an analytical solution and a numerical solution based on stepped representation using uniform elements. Significance of the inclusion of taper considerations on solution accuracy was also provided.

Gupta [2,21] has derived static stiffness and consistent-transverse and rotary inertia matrices in explicit form for a linearly tapered beam of any cross-sectional shape. Dynamic stiffness and consistent mass matrices [2,22] have been derived in explicit form for the beam element of closed box of I-Section. These matrices were derived by the finite element method using an exact-expression for the required displacement functions obtained from solution of the equation of motion. Variation in area and moment of inertia of cross section along the axis of the element is exactly represented by simple func-

tions involving shape factors; this variation is used in the equation of motion. Numerical results of vibration analyses for some beams were obtained using the derived matrices and compared with available analytical solutions and approximate solutions based on stepped representation of the beams using uniform elements. Results of the investigation showed that convergence of the frequencies to then exact values, at the same level of grid refinement, is much faster when dynamic matrices are used instead of a conventional formulation, especially in the range of coarse idealization and higher modes. It was further observed that the severity of taper within the beams significantly affects the accuracy and convergence characteristics of the solution obtained from the stepped representation of the beams; practically no effect was observed on solutions obtained from tapered element idealization. Rotary inertia has a significant influence on the vibration frequenci.s of the beams [2,23].

A static stiffness matrix has been presented for a beam element of rectangular cross section with constant width and linear variation in depth [24,25], Results for a tapered cantilever beam using the above matrix and a consistent mass matrix [7] are given. These results were compared for accuracy and computational efficiency with those obtained using static and dynamic stiffness matrices and lumped and consistent mass matrices for uniform or tapered elements.

Flexural, axial, and geometric stiffness and consistent-mass matrices have been given for a beam element of constant width and linearly varying depth [3,26]. The beams can have arbitrary cross section with a vertical axis of symmetry, constant width, and linearly or nonlinearly varying depth. The general stiffness matrices are the same as those of Just [11]; they were derived using displacement functions obtained from solving the pertinent governing equations. Explicit expression for stiffness matrices for beam elements of rectangular, box, or I-section are provided. Following Lindberg's approach [12] explicit expressions for an approximate flexural stiffness matrix of a linearly tapered beam element with box or I-section were derived using a cubic displacement function. The element consistent mass matrix was constructed using the cubic displacement function of a uniform beam element. Results are given for a tapered cantilever beam, a continuous beam, and a gable frame with uniform and nonuniform members; the various approaches described above were used.

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LITERATURE REVIEW: survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four reviews each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the **DIGEST** reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

THEORETICAL STUDIES ON FLEXURAL WAVE PROPAGATION IN BEAMS: A COMPREHENSIVE REVIEW – PART II: TRANSIENT RESPONSE OF TIMOSHENKO BEAMS

M.M. Al-Mousawi*

Abstract. A comprehensive review related to the problems of flexural wave propagation in beams is presented in three parts. Part I is a historical background. Part II describes the use of Timoshenko beam theory, including the effect of shear distortion and rotatory inertia, for vibrational and transient analysis of beams. Part III covers elastic stress wave propagation in beams with discontinuities of cross section.

THE TIMOSHENKO BEAM THEORY

The Timoshenko beam theory is applied to the flexural vibration of beams. The problem of transient flexural wave propagation is also described.

Flexural vibration of beams. The simplest theory governing the flexural vibration of beams, the Euler-Bernoulli theory, assumes that deformation of the bar element is in the form of transverse displacement only. Other assumptions include uniform homogeneous and constant cross section, small deflection, and plane cross sections that remain plane and perpendicular to the neutral axis after deformation. Thus, shearing deformations are neglected. The Euler-Bernoulli equation for bending vibration also neglects the rotatory-inertia effect. However, at low frequencies, the theory is satisfactory for the frequency spectrum and mode shape of beams in steady-state harmonic vibration.

The Pochhammer-Chree theory includes a set of equations for flexural vibrations and is applicable only to an infinite bar in which continuous sinusoidal waves are propagated in either direction. This three-dimensional theory of elasticity cannot be used to construct solutions for finite and semi-infinite bars. In addition, the frequency equations are very complex and therefore difficult to use for practical solutions.

Even though the Timoshenko beam theory is approximate and one-dimensional, remarkable agreement with the exact theory of elasticity is possible in the case of an infinite bar of circular cross section, especially in the first branch of the dispersion curve. This is the primary flexural mode [13]. The Timoshenko theory is more accurate than the Euler-Bernoulli theory for transverse and flexural free and forced vibrations of a beam; frequency equations, displacement curves, and mode shapes are determined. The Euler-Bernoulli equation can be obtained directly from the Timoshenko beam equations if the terms that account for the effects of rotatory inertia and shear deformation are omitted.

Bresse [6] was the first person to discuss the effect of nonuniform shear distribution over a cross section and to include a term for the effect of rotatory inertia in his equation of motion for lateral vibration. However, Timoshenko first included both terms in the equation for flexural vibration of beams; therefore, the theory that accounts for these effects is credited to him. Timoshenko [4] derived the equation for flexural vibration and obtained a frequency equation for a simply-supported prismatic bar of length 1. He showed the importance of the correction for shear, which is sometimes several times greater than the correction for rotatory inertia. Timoshenko [10] also obtained a solution for the case of a beam of rectangular section; he found approximate solutions for the cases of plane strain and plane stress. He also studied a bar of circular cross section and suggested shear correction factors for both rectangular and circular cross sections. His solution was not applicable to other boundary conditions.

Goens [14] used the Timoshenko equations and obtained complex exact expressions for the case of a free-free beam. These expressions yield vibration frequencies by an approximate numerical evaluation for bars of circular cross section and various lengths. Goens used his results to determine Young's modulus.

Davies [15] investigated the transverse vibration of a fixed-free bar under the effects of a shear force and bending moment. He used the Timoshenko beam equation to solve frequency equations that satisfied the boundary conditions. The

* University of Aberdeen, Department of Engineering, Kings College, Aberdeen, Scotland

solutions were approximations of series expansions in which terms of higher orders were neglected. Fundamental modes were determined for bars of different materials and dimensions. The importance of the effects of rotatory inertia and shear were emphasized.

Kruszewski [16] found general solutions for the Timoshenko beam equations and solved them for uniform cantilever and free-free beams. He presented graphically the frequencies of the first three modes. His results showed that the effect of shear increases in the higher modes and causes a significant decrease in the frequency value.

Sutherland and Goodman [17] found that shear distortion is particularly important at higher frequencies. Their general solution for the lateral free vibration of a pin-ended beam and natural frequencies was for a simply supported and for a cantilever beam.

Traill-Nash and Collar [18] pointed out that a complete new spectrum of natural frequencies appears when both shear flexibility and rotatory inertia are taken into account. The importance of higher frequencies in bending vibration was shown in connection with such aircraft components as wings, fuselages, and propellers. They investigated various types of end conditions. The first five natural frequencies were calculated using a matrix iteration process; the effect of shear flexibility was considerable.

Anderson [19] compared various solution methods for flexural vibrations based on the Timoshenko beam theory. He pointed out certain advantages of power series expansions, according to the principles of superposition, over Laplace transformation solutions. This series solution is the same as one published previously [17] for the case of a simply-supported beam. The slight numerical difference in the values of the graphs is due to the somewhat higher value used for the shear correction factor.

Dolph [20] pointed out the existence of two sinusoidal modes of different frequencies corresponding to the same spatial factor in solutions based on Timoshenko theory. He considered the separation of variables and orthogonality relations as in a typical eigenvalue problem. He presented a normal mode solution for a uniform hinged-hinged beam.

Howe and Howe [21] demonstrated the usefulness of an electronic differential analyzer for determining solutions for lateral vibration of beams according to the Timoshenko beam theory. They based their solution on a system of four simultaneous first order differential equations previously given by Dolph [20]. They paid particular attention to the mode shapes. A satisfactory solution according to the normal mode method, applied to the case of a free-free beam, required six trials.

Huang [22,23] investigated the effects of rotatory inertia and shear on the flexural vibration of beams. He obtained a solution for the Timoshenko beam equation by applying the energy method of Ritz to a simply-supported beam. He also presented frequency equations for a combination of various types of end conditions using normal mode solutions.

From 1965 to 1980 the finite element method was applied to the bending vibration of beams treated by the Timoshenko theory. Several Timoshenko beam elements were developed; a brief summary of research published in this area is given below.

Hurty and Rubenstein [24] used an energy approach to develop generalized mass matrix and stiffness matrix, including the effect of rotatory inertia and shear. These effects were illustrated in natural frequencies and corresponding mode shapes for uniform simply-supported beams. Archer [25] presented a consistent mass-matrix and a stiffness-matrix for the vibration analysis of a Timoshenko beam. Kapur [26] derived a finite element for the Timoshenko beam in which a cubic plynomial function was assumed for both bending and shear deformation. No coupling between the two displacements was permitted; hence, the problem was overspecified.

Egle [27] presented an approximate Timoshenko beam theory designed to eliminate coupling between shear deformation and rotatory inertia. Nickel and Secor [28] derived stiffness and mass matrices for what they called TIM 7, a matrix of order 7, that was reduced to TIM 4 using the constraint given by Egle [27]. An element model similar to TIM 4 had a limitation such that natural boundary conditions at the free end or hinged end could not be applied [29].

It has been pointed out [30] that errors in the matrices of one element given by Archer [25] caused confusion and led to unacceptable results. An element with three degrees of freedom at each of the two modes was proposed to calculate the natural frequencies of a cantilever beam [30]. The results were compared with those of other elements.

Dong and Wolf [31] used quadratic interpolations for the displacement variables of a finite element for the Timoshenko beam. They used Hamilton's principle to derive the equations of motion in discrete coordinates and obtained frequencies for a simply-supported beam, two-bay frame, and hinged arch. Ramamurti and Mahrenholtz [32] used simultaneous iteration methods to determine eigenfrequencies for a flexural vibration problem. They concluded, from the relatively high differences between theoretical and experimental frequency values, that the actual structure had to be modified to reduce the number of modal points to meet the available storage of the computer.

Thomas and Abbas [33] suggested four nodal degrees of freedom for a two-noded Timoshenko beam finite element that incorporated natural boundary conditions. The mass and stiffness matrices are based on cubic polynomial expansions; total deflection and bending slope are derived from energy expressions. It has been noted [34] that it is not possible to claim that any one element as the best vibration analysis of Timoshenko beams. The choice of element must depend on accuracy required, nature of the structure, relative importance of shear and rotatory inertia, and number of degrees of freedom available.

Downs [35] detected an additional mode due to shear oscillation when he reexamined various equations [20-23]. This mode was identified in the frequency discretized analysis of an eight-segment simply-supported uniform Timoshenko beam; a finite element solution using consistent mass theory was also used. A finite element model for vibration of nonuniform beams has been suggested [36]. Bishop and Price [37] used the Timoshenko theory in a dynamical structural analysis of ship hulls as a nonconservative system.

Transient flexural wave propagation in beams. The Euler-Bernoulli theory is inadequate for transient bending wave propagation problems because the theory assumes that disturbances with infinitely short wavelengths, which are associated with high frequency branches, will propagate with an infinite velocity. The transient input gives rise to higher frequencies when the duration of impact is much smaller than the fundamental period of vibration of the structure. Hence, according to the Euler-Bernoulli theory, transient disturbances should be felt immediately at the far end of a beam. This effect is physically impossible and contrary to the results of the Pochhammer-Chree theory, which predicts finite values for the velocity of propagation of stress waves. Furthermore, the Euler-Bernoulli theory assumes that the displacement of a bar consists solely of translation.

The complexity of the displacement and frequency equations makes the exact theory impossible for practical problems of flexural wave propagation. In addition, the exact theory cannot satisfy the end conditions with zero stresses at the lateral surfaces. However, the Pochhammer-Chree theory has been used to determine phase velocities and group velocities of sinusiodal waves in narrow beams and beams of circular cross section.

Dispersion relations play an important role in the propagation of flexural waves in elastic bounded solids. A pulse can be seen as the Fourier integral of a number of sinusiodal components of different frequencies. The components will travel with different velocities; dispersion causes distortion of the wave. Dispersion analysis required determination of the variation of phase velocity c_p -- i.e., the velocity of propagation of surfaces in which phase varies with wavelength -- as well as group velocity c_g, which is the velocity of propagation of a wave packet of almost the same wavelength. For flexural waves, group velocity is more important because it is the rate at which energy is transmitted.

The Timoshenko beam equation, which takes into account the effects of rotatory inertia and shear on the displacement of a beam, provides a high degree of accuracy over a wide range of wavelengths for flexural waves in bars. From an engineering point of view the Timoshenko theory is the best known theory for dealing with transient flexural wave propagation. The Timoshenko beam theory provides dynamic equations of motion for transient waves in infinite, semi-infinite, and finite beams. The Timoshenko beam equations are applicable to flexural waves due to transverse impact as well as eccentric longitudinal impact.

In some cases results obtained by theoretical models have been compared with experiments. This work is summarized briefly. Timoshenko [38] investigated the transverse impact of a simply supported beam of square cross section. He used the theory of lateral vibration and the Hertz theory to evaluate numerically the deflection of a short beam 15.35 cm long and 1 x 1 cm in cross section that was struck in the middle by a steel sphere of 1 cm radius. He considered transformation of the kinetic energy of the striking mass into the potential energy of bending in the beam and estimated the energy loss due to impact. The integral equations were solved

numerically by dividing the time into small increments during which the contact force between the striking mass and the beam could be considered constant.

The same problem of a central impact of a simply supported beam was investigated by Arnold [39]. He compared experimental results with theoretical calculations based on the Timoshenko analysis. A more detailed theoretical study of the same problem is also available [40].

Lennertz [41] calculated the fundamental period and the maximum deflection of the two simply-supported beams discussed by Timoshenko [38] and obtained comparable results. He considered the impact as a whole rather than as a succession of steps. Lennertz assumed that the duration of impact was small compared with the period of the fundamental mode of vibration. This assumption is acceptable only if the fundamental modes is the only one stimulated; thus, the effects of higher mode would be neglected. Such an assumption is not justified.

Lee [42] improved the method used by Lennertz with a modified Hertzian expression to obtain a solution for central impact of a uniform simply-supported beam. His calculations compared well with the experiments of Arnold [39].

Bancroft [43] solved the Pochhammer-Chree equations for the propagation of longitudinal waves. He formulated propagation velocity in terms of two variables: the Poisson's ratio and the ratio of the bar diameter to wavelength. He discussed qualitatively the flexural mode and pointed out the complexity of the flexural modes. He obtained only the lowest root of the equation.

Prescott [44] found the frequency equation in determinantal form for the case of flexural vibration, but he did not evaluate the determinant derived from the exact theory of elasticity. He also derived the Timoshenko beam equations by energy considerations and found that the elementary theory of transverse vibration was inadequate for transient loadings. The velocity of flexural waves depends on their wavelength and approaches that of Rayleigh surface waves when the wavelength becomes small compared with the lateral dimensions of the bar. Prescott obtained numerical results for the velocity of flexural waves in a bar of circular cross section.

Flügge [45] observed that the Timoshenko theory predicts that discontinuities are propagated at finite velocities,

$$c_1 \ (=\sqrt{E/\rho}) \text{ and } c_2 \ (=\sqrt{k^2 G/\rho}).$$

He pointed out that discontinuities of bending moment and angular velocity are propagated with c_1; discontinuities of shear force or transverse velocity are propagated with c_2.

Hudson [46] solved the determinant of the frequency equation by Prescott [44] for flexural vibration. Hudson presented dispersion curves for various values of Poisson's ratio but overlooked the higher modes of the flexural waves and incorrectly assumed that they did not exist.

Cremer [47] discussed two velocities that appear in the Timoshenko equation. He pointed out that better agreement with exact theory can be reached if the value of the shear correction factor is adjusted so as to produce a value for the shear velocity c_2 that corresponds to the asymptotic value of the lowest mode of the exact theory. Davidson and Meier [48] used the Timoshenko beam theory to study the propagation of transverse waves in prismatical bars. They were interested in slender tools used in the percussion drilling of rock. Eccentric longitudinal impact was studied experimentally.

Pfeiffer [49] used the method of characteristics in a general solution of the Timoshenko beam equation as a system of two second order partial differential equations. He discussed the propagation of discontinuities and described the steps needed to carry out the numerical calculation. However, Pfeiffer did not present a numerical example. Cooper [50] discussed the dispersive nature of longitudinal and flexural waves on the basis of the exact theory. He pointed out that it is difficult to get information other than that the maximum velocity propagation for any disturbance is the velocity of dilatational waves c_D.

Davies [13] verified the Pochhammer-Chree theory experimentally and pointed out the differences between the elementary theory of transverse vibration and this exact theory. Davies constructed dispersion curves for flexural waves. He obtained phase velocity and group velocity for the first bending modes at a Poisson ratio $\gamma = 0.29$. The values for the flexural curve based on the exact theory were interpolated from Hudson's data. The dispersion curves derived from the Timoshenko theory agreed well over a wide range of a a/Λ with the values derived from the exact theory. Davies concluded that predictions based on the Timoshenko theory for the velocity of propagation of the leading edge of a flexural pulse --i.e., $c2 = \sqrt{k^2 G/\rho}$ -- differ from results based on the exact theory by only a small percentage for almost any form

of cross section. However, flexural pulses would be propagated with higher velocities if higher branches of the dispersion curves are considered. Davies included extensive experimental results based on a modified Hopkinson pressure bar. These results justified assumed uniform distribution of stresses over the cross section and hence use of the one-dimensional theory.

Uflyand [51] used the Timoshenko beam equation to solve the problem of an infinite beam subjected to a concentrated load of a step-function time history. He used Laplace transformation to obtain displacement solutions and showed that contour integration would give exact traveling wave solutions for the theory. He approached the problem by cutting the infinite beam at a station to one side of the load; he treated the unloaded, semi-infinite portion of the beam. But his interpretation of the assumed boundary conditions was incorrect.

De Juhasz [52] presented a graphical analysis of several longitudinal impact problems. His objective was to avoid difficulties involved in mathematical analysis. Three-dimensional diagrams, or stereograms, were constructed from x-t diagrams and v-p diagrams. The graphical analysis was based on two assumptions: constant velocity of propagation and a linear relationship between the change of striking velocity v and the change of stress. Although no dispersion relations were involved, the stereograms were too complicated even for basic problems of longitudinal impact of bars.

Duwez [53] studied the deformation of an infinitely long beam subjected to a concentrated transverse load of constant velocity. He investigated the influence of impact velocity and duration of impact on the deflection characteristics of the beam. The plastic deformation of steel was assumed to be localized at the point of impact. However, for such soft materials as annealed copper plastic deformation had to be considered. The discrepancies between theoretical and experimental results were attributed to the effects of end supports and the dispersion characteristic of the transverse waves.

Derivations and approximate theories for transverse waves in plates and two-dimensional compressional waves in bars were stimulated by the Timoshenko beam theory. Mindlin [54] used three-dimensional equations of motion to deduce a two-dimensional theory for flexural motions of plates. The theory accounts for the effects of rotatory inertia and shear in the same manner as Timoshenko's theory. Mindlin's theory was similar to that of Uflyand [51] and Reissner [55].

Mindlin and Herman [56] derived from the general theory of elasticity a one-dimensional theory of compressional waves in elastic rods. They obtained equations for radial and longitudinal motions of a bar that were similar to Timoshenko's equations for rotational and transverse motions of a beam and could be treated in a similar manner.

Dengler and Goland [57] pointed out that the boundary conditions of Uflyand [51] were incorrect and solved the same problem. They avoided the boundary conditions by working with the original fourth order nonhomogeneous Timoshenko equation. A lateral impulsive load was applied to the beam at the midpoint in the form of a two Dirac function product in terms of t and x. The results appeared in closed form solutions and required the evaluation of complicated integrals. Another difficulty was that of defining proper boundary conditions in the total deflection approach. The contour analysis included an error in connection with singularity problems; the error was corrected in a later publication [58].

Schirmer [59] discussed the problem of flexural waves in a Timoshenko beam and compared solutions based on a system of two second-order partial differential equations in terms of transverse displacement y, angular rotation ψ, and their derivatives. He used Laplace transformation for the dispersion analysis and the method of characteristics to obtain bending moment distribution along the beam at certain times after a bending moment input at one end.

Miklowitz [60] pointed out the difficulties in previous methods [51,57]; he modified the Uflyand method [51] and correctly interpreted his boundary conditions. Miklowitz treated the lateral deflection components due to rotary inertia and shear separately in essentially the same was as Schirmer [59]. This approach provided insight into the physical nature of the traveling wave, reduced the mathematical difficulties of establishing the boundary conditions, and allowed transformation for the case of an infinite beam under the action of a concentrated transverse load. It is not always easy to obtain transform solutions for various end conditions; it is even more difficult to evaluate them numerically. Miklowitz [61] used the same method to obtain a traveling wave solution for flexural waves in plates.

Leonard and Budiansky [62] used the method of characteristics to obtain numerical traveling wave solutions for Timoshenko beams of various end conditions subjected to step velocity, step bending moment, and ramp-platform bending moments.

However, for mathematical simplicity, the solutions were based on the equality of the two propagation velocities; this assumption is physically unrealistic. The characteristic equation was based on the Timoshenko beam theory as as system of four first-order partial-differential equations. In some cases the solutions were compared with closed form and modal solutions.

Eringen [63] applied a generalized-Galerkin method and collocation method to Hertz's law to obtain contact force and displacement for transverse impact of beams and plates with various end conditions. Deflection curves were obtained by using Dirac δ -function with the same impulse as the contact force F(t).

Newman [64] solved the Timoshenko equation for a half-period sine excitation applied at the root of a cantilever beam. Appropriate initial and end conditions were specified by a variational principle. The relation between maximum dynamic strain and relative impact duration was plotted. Newman found that a thin slender bar (L/r=300) was subjected to 25.5 percent higher strain than a thick short bar (L/r=30) at the clamped end in short duration impact. Newman used Laplace transformation for his frequency-based analysis.

Boley and Chao [65] presented a Laplace transformation solution of the Timoshenko beam equations for transverse impact of semi-infinite elastic beams. Laplace transformations were used for various types of sudden loadings. The curves obtained for bending moment and shear force for several positions were compared with results of elementary beam theory.

Boley [66] described the behavior of beams under lateral impact by an approximate traveling-wave approach based on energy considerations. Numerical results were obtained over a very short time for a very short portion of the beam close to the point of impact. However, these short-comings were later removed from this method, and solutions were obtained for semi-infinite beams under step-inputs of velocity and bending moment [67]. Deflection curves for finite simply-supported beams were constructed by superposition of semi-infinite beam results according to the method of images [62].

Jones [68] used Fourier transforms to obtain a solution for flexural stresses in an infinite beam loaded by a transverse point load. His solution was based on Timoshenko's theory of transverse vibration; asymptotic approximations were found by the method of stationary phase. Numerical evaluations for variations in amplitude of bending moment and in wavelength were presented.

Barnhart and Goldsmith [69] developed a theory for the transverse impact of spheres on elastic beams. The theory incorporated a dynamic plastic force-identation law and permitted evaluation of the effect of an arbitrarily large number of beam bending modes. The theoretical stress-time histories accounted for higher modes. The histories were in better agreement up to the peak value with observed data than curves based on Hertz's law. The shape of these curves during initial loading increase did not agree well with experimental results. However, the peak value obtained by both methods was in fair agreement with experimental results at the point of impact.

It has been pointed out [70] that Hudson [46], who calculated the first root of the frequency equation, incorrectly assumed that flexural waves are propagated only in one mode. The three lowest modes of the determinant of flexural wave transmission, based on the Pochhammer-Chree theory, were calculated [70]. Dispersion curves presented for $\nu = 0.29$ were used to study the rate of energy transmission in terms of group velocity to gain insight into the physical phenomena involved in the flexural response of beams to impulsive loads.

Ripperger and Abramson [71] compared predictions of the Pochhammer-Chree theory concerning the arrival time of flexural waves with experimental results. They found that initial disturbances were propagated at the dilatational wave velocity and that the bending wave pulse was propagated by a continuous series of arrivals. They established the adequacy of the Timoshenko beam theory in accurately predicting arrival times for all but the very sharpest impact. Amplitude response is also predicted by the Timoshenko theory. It was concluded that, for all practical purposes, the Timoshenko theory provides an adequate representation of the propagational characteristics of bending waves.

Plass [72] extended the method of characteristics to the general case of different propagation velocities. He studied various types of end conditions for Timoshenko beams under a half-sine form of end impacts of moment, shear, angular velocity, and transverse velocity. He solved the case of a simply-supported semi-infinite beam under the action of a sinusoidal end moment by both Laplace transforms and the method of characteristics. Comparison with experimental data [73] showed good agreement except when the pulses were extremely short.

Flügge and Zajec [74] investigated several methods other than the method of characteristics; none of them could yield a complete solution at all points of the beam. However, a combination provided an almost complete solution for a semi-infinite, simply-supported beam under the action of a step-function end bending moment. Numerical results close to the end were obtained with the Laplace transformation and term-by-term inversion. For long time intervals the integral obtained from contour integration close to the point of impact was evaluated to obtain asymptotic solutions. The stationary phase method of Kelvin was used. A complex combination of several not-so-easily obtainable functions -- the Bessel function, Laplace transforms, and Fourier transforms -- was involved.

Kuo presented [75,76] results of a theoretical and experimental study of bending waves in a semi-infinite Timoshenko free-free beam subjected to a dynamically applied end moment. He used the method of characteristics. In order to simplify the numerical analysis he made k^2G/E equal to unity. This is the same as two equal characteristic velocities and is physically incorrect. Results of studies on the effects of slenderness ratio and change in rise-time were compared with a theoretical treatment based on Euler-Bernoulli theory by the normal mode method. Comparison of results of Timoshenko beam theory and observed data was limited to the initial stress buildup. The discrepancy was most marked in the phase shifting.

Jones [77] used the exact two-dimensional theory of plane-strain transverse waves in a beam. He applied a transverse force with a step function time variation. The bar width was great in comparison with its depth; i.e., the bar was in the form of a plate. The solution was used to assess the validity of Timoshenko's theory and its advantage over elementary theory.

Chou and Mortimer [78] pointed out the advantages of the method of characteristics over the mode superposition method and the Laplace transform method for solving transient response problems. They used the method of characteristics for several elastic wave propagation problems, including the Timoshenko beam equation; the problems were treated as a system of second-order hyperbolic partial differential equations. Governing equations for the propagation of discontinuities along characteristic lines were obtained. Various types of input loadings were used along the characteristic lines to evaluate time histories of stresses. The method was an improvement on the numerical method of Chou and Konig [79] regarding propagation of discontinuities. Chou and Koenig [79] compared their results for the method of characteristics with the results of other methods and found excellent agreement.

Davids and Koenig [80] used a so-called direct finite element analysis to solve a dynamic flexural traveling wave problem in infinite beams and plates. They used Timoshenko beam theory to obtain numerical results for a very short cantilever beam with a step velocity input applied at the free end. The effect of reflection on the evaluated bending moment and shear force was included.

Bejda [81] investigated the propagation and reflection of stress waves in elastic-visco plastic beams; he used the method of characteristics for both regions. Numerical results were obtained for a cantilever beam under suddenly applied bending moment and shear force to the free end.

Edge [82] investigated the response to impact hook units used to stop aircraft. He used two numerical wave propagation methods: the method of characteristics and the direct finite element analysis. His solutions based on the Timoshenko beam theory were for both naval and land-based aircraft hook units. He pointed out the advantage of the method of characteristics for obtaining bounce dimensions in land-based cases.

Garrelick [83] considered the response of a link spring-supported beam subjected to a uniform velocity input. He represented the Timoshenko theory as a conservative second order hyperbolic system and used a dual eigenfunction expansion in which the system consisted of real and positive eigenvalues and orthogonal eigenfunctions. The results for the moment at the center and the shear at the support were compared with the results of the Euler-Bernoulli theory. Discrepancies were greatest close to higher oscillations representing reflected wave fronts. The results may be applicable to sonic boom problems and problems in packaging.

Ranganath [84] employed the Timoshenko theory to solve the problem of transverse impact of an infinite elastic beam by a semi-infinite elastic rod. The hyperbolic equations were solved by Laplace transformation and compared with experimental data and a second theoretical solution obtained by a finite difference technique. Both theoretical results correlated closely with observed data; the finite difference method was in better agreement. Discrepancies at initial times and at stations close to the point of impact were

reflected in oscillations at early times. These discrepancies were not supported by experimental observations of the strain waves.

Lee and Kolsky [85] based their investigation of flexural waves generated at the junction of two non-collinear rods on the Timoshenko theory. They considered transmitted and reflected flexural waves; the shape of the initial pulse was assumed as the integral of the difference between two error functions separated by pulse length and expressed in an inverted Fourier cosine transform. Four waves were generated at the junction: two longitudinal pulses and two flexural pulses in which both types reflected back along the first rod and also transmitted into the second rod inclined at various angles to each other. The shapes of the four waves were determined and compared with experimental results.

Sagartz and Forrestal [86] compared the Timoshenko solution with the Euler-Bernoulli solution and with experiments for flexural waves propagating form the clamped end of an impulsively loaded semi-infinite cantilever beam. The transform method was used to find a solution for the hyperbolic Timoshenko beam equations. Results were compared with observed data in which the input pulse was assumed to have the form of a sine-squared uniform lateral pressure pulse. The effects of shear deformation and rotatory inertia were especially important at the initial time.

Philips and Crowley [87] treated pulse propagation in a curved beam by the Timoshenko theory. They used the method of characteristics for the numerical solution. The input pulse was in the form of a half-sine pulse. Similarities to the problem investigated by Lee and Kolsky [85] were pointed out. They concluded that a flexural pulse in a curved beam of moderate curvature is insensitive to the actual beam curvature insofar as bending moment and shear are concerned. These results are in agreement with conclusions of Morley [88], who showed that no significant interaction occurs between extension and flexure for small curvature.

The accuracy of the results of a two-dimensional elastic-plastic wave propagation computer code TOODY have been assessed by comparison with those based on Timoshenko beam calculations for an impulsively loaded simply-supported beam [89]. The transient pulse was a sine-squared pressure pulse of very short duration. General agreement between the two theoretical predictions was good except that higher frequency oscillations were predicted by TOODY.

Colton and Herrman [90] used the Timoshenko beam theory to calculate beam response before, during, and after fracture. The method of characteristics was employed to obtain strain histories under localized impulsive loading of a beam of rectangular cross section; three models of the fracture were postulated. Comparison of calculated and measured strains showed that a two-stage fracture model approximated the structural response. A similar investigation [91] showed that all fractures were initiated by bending stress.

Parker and Neubert [92] obtained the transient lateral response of a cylindrical rod with free ends to a short duration half-sine pulse when either moment or shear was applied to one end. They used the mode shapes and frequency equations of Huang [93] as well as classical separation of variables. The modal series solutions involved many modes for the Timoshenko beam theory with time-dependent boundary conditions. The theoretical solutions predicted higher peak values when compared with experimentally observed data [73].

Sun and Huang [94] developed a higher order finite element of a beam by increasing the nodal degrees of freedom to three. They tested the efficiency of the element for impact problems concerning the response of a simply-supported beam subjected to a sine pulse and the impact of a steel sphere on a cantilever beam. Displacement curves and contact force histories were in good agreement with existing solutions.

Tanaka and Motoyama [95] investigated an infinite circular bar subjected to impulsive bending load. They used the three-dimensional theory of elasticity and compared dispersion relations with those obtained from several approximate theories. Results of the Timoshenko beam theory conformed to those of the exact theory over the entire region for the first mode and over a small region of the second mode. Laplace transforms and Fourier transforms were used in the analysis. Tanaka and Iwahashi [96] reported a similar analysis for a bar of rectangular cross section. The solution was obtained by an approximate crosswise superposition of two series solutions. Dispersion curves for the frequency spectrum of the bending mode were in good agreement for the fundamental branch when compared with results of the Timoshenko theory.

A controversial brief note by Nicholson and Simmonds [97] suggested that, for an elastic isotropic beam of narrow rectangular cross section and clamped at one end, the Timoshenko beam theory is no more accurate than elemen-

tary beam theory. This provoked seven discussions [97], all of which emphasized the importance of the Timoshenko theory as a valuable engineering tool; the unusual nature of the example chosen was criticized. It was pointed out that the Timoshenko beam theory yields accurate numerical results but is not a consistent theory from the point of view of asymptotic theories.

The problems of elastic wave propagation in rods and beams have been surveyed in many articles [98]. One survey [99] contains extensive information on various types of waves propagated in rods and beams. Two others [61,100] contain discussions of the transient wave propagation problem in beams and rods. Reviews of experimental and theoretical advances in the propagation of waves in elastic solids are available [101,102]. An annotated bibliography has been published that contains a few recent references on flexural wave propagation in rods [103].

Detailed treatments of the theory of wave propagation in elastic solids are available in books. Those by Kolsky [104] and Goldsmith [105] can be considered standards of the modern history of elastic waves. A recent revival of interest in the subject led to the publication of many books in the 1970s that included comprehensive treatments of wave propagation problems and bibliographies [1,106,107].

Reasons for interest in this subject during the last three decades include the rapid development of computing facilities, the advance of experimental equipment available for producing and detecting stress waves, and the need for information on the behavior of structures subjected to impulsive loading. There is also an overwhelming increase in the literature related to the field of geophysics and acoustic and electromagnetic waves.

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BOOK REVIEWS

REVIEW OF NONLINEAR OSCILLATIONS, DYNAMICAL SYSTEMS, AND BIFURCATIONS OF VECTOR FIELDS

J. Guckenheimer and P. Holmes
Springer Verlag, Inc., New York, NY
1983, 453 pages, $32.00

Indicative of the background necessary to read this book are the review topics presented in Chapter One: theorems on existence and uniqueness of solutions to ordinary differential equations; stability theory, including Liapunov methods; the concepts of a flow and an invariant subspace; linear, nonlinear, and Poincare maps; Floquet theory; and attracting and repelling sets. Clearly this is no book for the novice. I suspect that the average engineer will find the going tough. On the other hand, he or she will be richly rewarded. This book offers a unique blend of abstract theory and concrete physical examples and details about a variety of phenomena.

A goal of Chapter Two is to illustrate bifurcations, chaotic motion, and strange attractors. It opens with a study of Van der Pol's equation. For weak nonlinearities the method of averaging is used to show the existence of limit cycles. Relaxation oscillations are exhibited for a strong nonlinearity. Phase-locking and entrainment are shown for forced motions, and an exhaustive catalog of the various types of bifurcations that can occur is given. Representations, or orbits, of maps as symbol sequences -- known as symbolic dynamics -- are briefly illustrated. Results on the Duffing equation are discussed and include those from an experiment on the electromagnetic forcing of a cantilever beam. The chapter closes with additional illustrations of the Lorenz equations and the dynamics of a bouncing ball.

Chapter Three is analytical in nature and is devoted to the study of local bifurcations; special attention is given to the examples in Chapter Two. Sadde-Node, transcritical, pitchfork, and Hopf bifurcation are examined and illustrated. The theme of Chapter Four is the geometrical interpretation and elaboration of some standard approximation techniques. Considerable space is devoted to the method of averaging and to Melnikov's method.

Chapter Five is very technical. Introductory remarks can be paraphrased as follows: a description is given of both the irregular character of individual solutions and the complicated geometric structures associated with their limiting behavior. The principal technique used is symbolic dynamics, the theory of which is not systematically introduced. Instead, some of the major results are stated. The solving of specific problems is achieved through numerical or perturbation methods, followed by the methods of this chapter.

Chapters Six and Seven describe global bifurcations. To quote from the preface .. "We discuss global homoclinic and heteroclinic bifurcations, bifurcations of one-dimensional maps ... in our discussion of global bifurcations of two-dimensional maps and with hyperbolic sets, we arrive squarely at one of the present frontiers of the field. We argue that ... the behavior of two-dimensional diffeomorphisms ... is still incompletely understood. In the final chapter we show how global bifurcations ... reappear in degenerate local bifurcations, and we end with several more models of physical problems which display these rich and beautiful behaviors".

This book is an absolute must for those interested in modern theoretical dynamics. However, be prepared for a considerable investment of time in order to digest the material.

R.A. Scott
Dept. of Mech. Engineering
and Applied Mechanics
University of Michigan
Ann Arbor, Michigan 48109-2121

MASCHINENDYNAMIK

E. Kramer
Springer Verlag, New York, NY
1984, 362 pages, DM 118 (in German)

The author states that the book is written first of all for the practitioner with a technical university level background in mechanics and mathematics. The book is intended to enable the reader to represent complex systems by simple mathematical models for preliminary analysis

and to use computer programs correctly and sensibly. The latter requires, according to the author, a thorough understanding of the mechanics and mathematics contained in the programs.

The book is concerned with vibration analysis of machines represented by linear models. The following topics are covered in the chapters: kinematics of free vibration and plane motion; mathematical models of elements with axial, flexural, and torsional deformations and springs for vibration insolation; models for viscous, Coulomb, and material damping; mass geometry; principles of kenetics; vibration of single-degree-of-freedom systems; matrix analysis of structures; vibration of multi-degree-of-freedom systems; dynamics of structures represented as discrete models; vibration of one-dimensional continua; and random vibrations.

The book is well written. However, it lacks numerical methods -- e.g., for the solution of eigenproblems and equations of motion by direct integration -- used in computer analysis.

S.M. Holzer
Dept. of Civil Engineering
Virginia Polytechnic Institute and
State University
Blacksburg, VA 24061

SHORT COURSES

JUNE

VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION
Dates: June 2-6, 1986
Place: Santa Barbara, California
Dates: August 18-22, 1986
Place: Santa Barbara, California
Dates: October 6-10, 1986
Place: Boston, Massachusetts
Dates: November 3-7, 1986
Place: Orlando, Florida
Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis; also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos Street, Santa Barbara, CA 93105 - (805) 682-7171.

VIBRATION CONTROL
Dates: June 9-13, 1986
Place: San Diego, CA
Objective: Participants in this course should leave with an understanding of the options available for vibration control, including general design considerations and such control techniques as isolation and damping. Lectures provide a sound review of vibration theory and develop the principles of vibration isolation and damping as they apply to particular design problems. Examples and case histories are used to illustrate design approaches; participants can solve problems during workshops.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

MACHINERY MONITORING
Dates: June 10-12, 1986
Place: Anaheim, California
Objective: The seminar focuses on the principles of vibration measurement for rotating machinery monitoring. Subjects covered in the seminar include troubleshooting, calibration and maintenance of monitoring systems, and the applications and installation of displacement, velocity, and acceleration transducers.

Contact: Bently Nevada's Customer Information Center, P.O. Box 157, Minden, NV 89437 - 800-227-5514, Ext. 9682.

VIBRATION DAMPING SHORT COURSE
Dates: June 16-19, 1986
Place: Dayton, Ohio
Objective: The science of applying viscoelastic damping technology to reduce structural vibration and noise has become well developed and successfully demonstrated in recent years. This course gives the participant an understanding of the principles of vibration damping technology necessary for the successful application. Topics included are: damping fundamentals, damping behavior of materials, layered damping treatments, tuned dampers, finite element techniques, case histories, problem solving sessions.

Contact: Michael L. Drake, The University of Dayton Research Institute, 300 College Park Avenue, Dayton, Ohio 45469 - (513) 229-2644.

MACHINERY DIAGNOSTICS
Dates: June 16-20, 1986
Place: Carson City, Nevada
Dates: June 24-27, 1986
Place: Denver, Colorado
Objective: This seminar instructs rotating machinery users on transducer fundamentals, the use of basic diagnostic techniques, and interpreting industry-accepted vibration data formats to diagnose common rotating machinery malfunctions. The seminar includes class demonstrations, case histories, and a hands-on workshop that allows participants to diagnose malfunctions on demonstrator rotor systems.

Contact: Bently Nevada's Customer Information Center, P.O. Box 157, Minden, NV 89437 - 800-227-5514, Ext. 9682.

DYNAMIC BALANCING
Dates: June 18-19, 1986
Place: Columbus, Ohio

Objective: Balancing experts will contribute a series of lectures on field balancing and balancing machines. Subjects include: field balancing methods; single, two and multi-plane balancing techniques; balancing tolerances and correction methods. The latest in-place balancing techniques will be demonstrated and used in the workshops. Balancing machines equipped with microprocessor instrumentation will also be demonstrated in the workshop sessions, where each student will be involved in hands-on problem-solving using actual armatures, pump impellers, turbine wheels, etc., with emphasis on reducing costs and improving quality in balancing operations.

Contact: R.E. Ellis, IRD Mechanalysis Inc., 6150 Huntley Road, Columbus, OH 43229 - (614) 885-5376.

JULY

FLOW-INDUCED OSCILLATIONS IN ENGINEERING SYSTEMS

Dates: July 1-2, 1986
Place: Bethlehem, Pennsylvania
Objective: The aim of this course is to provide the practicing engineer with a means of identification and assessment of the crucial flow mechanisms and flow-structure interactions leading to vibration and noise. Throughout the course, emphasis will be given to physical and practical interpretation of the common features of problems occurring in mechanical-, aerospace-, hydraulic-, and wind-engineering areas. The course will concentrate on the physical principles of identification, analysis, and attenuation (or cure) of oscillations, followed by practical case studies, during which the instructor will cover examples from a variety of applications.

Contact: Dr. James Brown, Lehigh Director of Continuing Education, Office of Continuing Education, 219 Warren Square, Lehigh University, Bethlehem, PA 18015 - (215) 861-3934.

VIBRATION DAMPING TECHNOLOGY

Dates: July 14-17, 1986
Place: Montreal, Canada
Dates: September 15-19, 1986
Place: Dayton, Ohio
Dates: January, 1987
Place: Clearwater, Florida
Objective: Basics of theory and application of viscoelastic and other damping techniques for vibration control. The courses will concentrate on behavior of damping materials and their effect on response of damped systems, linear and nonlinear, and emphasize learning through small group exercises. Attendance will be strictly limited to ensure individual attention.

Contact: David I. Jones, Damping Technology Information Services, Box 565, Centerville Branch USPO, Dayton, OH 45459-9998 - (513) 434-6893.

FINITE ELEMENTS IN MECHANICAL AND STRUCTURAL DESIGN A: LINEAR STATIC ANALYSIS

Dates: July 14-18, 1986
Place: Ann Arbor, Michigan
Objective: Presents energy formulation and modeling concepts. For engineers requiring stress, strain and displacement information. Attendees use personal computers to develop models of several problems and use MSC/-NASTRAN in laboratory sessions. No previous finite element experience is required.

Contact: William J. Anderson, Engineering Summer Conferences, 200 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109 - (313) 764-8490

MODAL TESTING OF MACHINES AND STRUCTURES

Dates: July 14-18, 1986
Place: Rindge, New Hampshire
Objective: Vibration testing and analysis associated with machines and structures will be discussed in detail. Practical examples will be given to illustrate important concepts. Theory and test philosophy of modal techniques, methods for mobility measurements, methods for analyzing mobility data, mathematical modeling from mobility data, and applications of modal test results will be presented.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

ROTOR DYNAMICS

Dates: July 14-18, 1986
Place: Rindge, New Hampshire
Objective: The role of rotor/bearing technology in the design, development and diagnostics of industrial machinery will be elaborated. The fundamentals of rotor dynamics; fluid-film bearings; and measurement, analytical, and computational techniques will be presented. The

computation and measurement of critical speeds vibration response, and stability of rotor/bearing systems will be discussed in detail. Finite elements and transfer matrix modeling will be related to computation on mainframe computers, minicomputers, and microprocessors. Modeling and computation of transient rotor behavior and nonlinear fluid-film bearing behavior will be described. Sessions will be devoted to flexible rotor balancing including turbogenerator rotors, bow behavior, squeeze-film dampers for turbomachinery, advanced concepts in troubleshooting and instrumentation, and case histories involving the power and petrochemical industries.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

ADVANCED TECHNIQUES FOR NOISE CONTROL
Dates: July 17-19, 1986
Place: Cambridge, Massachusetts
Objective: Among the topics to be covered are modern instrumentation for noise control, modal analysis, sound intensity applications, active techniques for noise control, structural and vibration transmission, and airport noise and monitoring systems.

Contact: Institute of Noise Control Engineering, P.O. Box 3206 Arlington Branch, Poughkeepsie, NY 12603.

FINITE ELEMENTS IN MECHANICAL AND STRUCTURAL DESIGN B: DYNAMIC AND NONLINEAR ANALYSIS
Dates: July 21-25, 1986
Place: Ann Arbor, Michigan
Objective: Covers vibration, material nonlinearities, and geometric nonlinearities. Includes normal modes, transient response, Euler buckling, and heat conduction. Attendees use personal computers to develop models of several problems and use MSC/NASTRAN in laboratory sessions.

Contact: William J. Anderson, Engineering Summer Conferences, 200 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109 - (313) 764-8490

FINITE ELEMENTS IN MECHANICAL AND STRUCTURAL DESIGN C: DESIGN SENSITIVITIES, CYCLIC SYMMETRY AND DMAP
Dates: July 28-August 1, 1986
Place: Ann Arbor, Michigan
Objective: Presents the use of design sensitivities and optimization (2 days), cyclic symmetry (1 day), DMAP programming (2 days). Attendees use MSC/NASTRAN to run sample problems in each topic. These methods greatly enhance the productivity and are now becoming widely used.

Contact: William J. Anderson, Engineering Summer Conferences, 200 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109 - (313) 764-8490.

AUGUST

DESIGN AND ANALYSIS OF ENGINEERING EXPERIMENTS
Dates: August 4-15, 1986
Place: Ann Arbor, Michigan
Objective: Recent developments in the field of testing, methods for designing experiments, interpretation of test data, and better utilization of the existing data. Design of experiments with a small number of test pieces or runs with high dispersion is emphasized. Obtaining maximum information from limited test data is stressed.

Contact: William J. Anderson, Engineering Summer Conferences, 200 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109 - (313) 764-8490.

MACHINERY VIBRATION ANALYSIS I
Dates: August 19-22, 1986
Place: New Orleans, Louisiana
Dates: November 11-14, 1986
Place: Chicago, Illinois
Objective: This course emphasizes the role of vibrations in mechanical equipment instrumentation for vibration measurement, techniques for vibration analysis and control, and vibration correction and criteria. Examples and case histories from actual vibration problems in the petroleum, process, chemical, power, paper, and pharmaceutical industries are used to illustrate techniques. Participants have the opportunity to become familiar with these techniques during the workshops. Lecture topics include: spectrum, time domain, modal, and orbital analysis;

determination of natural frequency, resonance, and critical speed; vibration analysis of specific mechanical components, equipment, and equipment trains; identification of machine forces and frequencies; basic rotor dynamics including fluid-film bearing characteristics, instabilities, and response to mass unbalance; vibration correction including balancing; vibration control including isolation and damping of installed equipment; selection and use of instrumentation; equipment evaluation techniques; shop testing; and plant predictive and preventive maintenance. This course will be of interest to plant engineers and technicians who must identify and correct faults in machinery.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

VIBRATIONS OF RECIPROCATING MACHINERY
Dates: August 19-22, 1986
Place: New Orleans, Louisiana
Objective: This course on vibrations of reciprocating machinery includes piping and foundations. Equipment that will be addressed includes reciprocating compressors and pumps as well as engines of all types. Engineering problems will be discussed from the point of view of computation and measurement. Basic pulsation theory --including pulsations in reciprocating compressors and piping systems -- will be described. Acoustic resonance phenomena and digital acoustic simulation in piping will be reviewed. Calculations of piping vibration and stress will be illustrated with examples and case histories. Torsional vibrations of systems containing engines and pumps, compressors, and generators, including gearboxes and fluid drives, will be covered. Factors that should be considered during the design and analysis of foundations for engines and compressors will be discussed. Practical aspects of the vibrations of reciprocating machinery will be emphasized. Case histories and examples will be presented to illustrate techniques.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

NEWS BRIEFS: news on current and Future Shock and Vibration activities and events

5th INTERNATIONAL MODAL ANALYSIS CONFERENCE AND EXHIBITS
IMPERIAL COLLEGE OF SCIENCE & TECHNOLOGY
LONDON, ENGLAND
APRIL 6-9, 1987

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- Space Structures
- Design Methods
- Processing Modal Data
- Noise/Acoustics
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The purpose of this Conference is to provide an international forum for all those concerned with the rapidly changing technology of modal analysis. Anyone interested in the dynamic behavior of mechanical structures will not want to miss this opportunity for technical interchange.

For further information contact:

Dominick J. DeMichele
Union College
Graduate & Continuing Studies
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ABSTRACT CONTENTS

AVAILABILITY OF PUBLICATIONS ABSTRACTED

None of the publications are available at SVIC or at the Vibration Institute, except those generated by either organization.

Periodical articles, society papers, and papers presented at conferences may be obtained at the Engineering Societies Library, 345 East 47th Street, New York, NY 10017; or Library of Congress, Washington, D.C., when not available in local or company libraries.

Government reports may be purchased from National Technical Information Service, Springfield, VA 22161. They are identified at the end of bibliographic citation by an NTIS order number with prefixes such as AD, N, NTIS, PB, DE, NUREG, DOE, and ERATL.

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Chinese publications, identified by a CSTA order number, are available in Chinese or English translation from International Information Service, Ltd., P.O. Box 24683, ABD Post Office, Hong Kong.

Institution of Mechanical Engineers publications are available in U.S.: SAE Customer Service, Dept. 676, 400 Commonwealth Drive, Warrendale, PA 15096, by quoting the SAE-MEP number.

When ordering, the pertinent order number should always be included, not the DIGEST abstract number.

A List of Periodicals Scanned is published in issues, 1, 6, and 12.

MECHANICAL SYSTEMS

ROTATING MACHINES

86-943
Estimating the Severity of Synchronous and Subsynchronous Shaft Vibration Within Fluid-Film Journal Bearings
J.D. McHugh
General Electric Company, Schenectady, New York
Vibrations, 1 (1), pp 4-8 (June 1985) 9 figs, 4 refs

KEY WORDS: Shafts, Synchronous vibration, Subsynchronous vibration, Vibration severity, Fluid-film bearings

Until now little information has been available for judging the degree of severity of shaft vibration within fluid-film bearings. This paper describes a method for estimating machine shaft vibration amplitude using basic bearing parameters -- provided vibration in the casing is not the predominant vibratory motion.

86-944
Coupled Torsional and Transverse Vibration of Unbalanced Rotor
R. Cohen, I. Porat
Technion-Israel Institute of Technology, Haifa, Israel
J. Appl. Mech., Trans. ASME, 52 (3), pp 701-705 (Sept 1985) 4 figs, 1 table, 10 refs

KEY WORDS: Rotors, Unbalanced mass response, Torsional vibrations, Flexural vibrations, Coupled response

A model of an unbalanced rotor, driven by a torsion-flexible shaft through a constant velocity joint, is used to investigate the combination-resonance effect in coupled torsional-transverse vibration. Analysis of the nonlinear equations of motion by an asymptotic method yields the instability zones of the system. Results are in very good agreement with those obtained by direct numerical solution of the equations of motion.

86-945
DEAN: A Program for Dynamic Engine Analysis
G.G. Sadler, K.J. Melcher
NASA Lewis Res. Ctr., Cleveland, OH
Rept. No. E-3588, NASA-TM-87033, 18 pp (1985)
N85-28945/2/GAR

KEY WORDS: Turbofan engines, Computer programs

The Dynamic Engine Analysis program, DEAN, is a FORTRAN code implemented on the IBM/370 mainframe for digital simulation of turbofan engine dynamics. DEAN is an interactive program which allows the user to simulate engine subsystems as well as a full engine systems. Following the transient run, versatile graphics capabilities allow close examination of the data. DEAN's modeling procedure and capabilities are demonstrated by generating a model of simple compressor rig.

86-946
Antivibration of Horizontal Precessional Centrifuges
Lu Shoudao
Beijing Institute of Light Industry
Dynamics of Machine Foundations, Proc. of Symp. Bucharest, Romania, pp 45-48 (Oct 22-24, 1985) 2 figs, 4 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Centrifuges, Vibration control

Precessional centrifuges are quite different in principle from other kinds of centrifuges. The drum of a precessional centrifuge rotates about a fixed point rather than about a fixed axis. Antivibration aspects of horizontal precessional centrifuges are discussed.

RECIPROCATING MACHINES

86-947
Torque on the Swashplate of an Axial Piston Pump
G. Zeiger, A. Akers
Iowa State Univ., Ames, IA
J. Dynam. Syst., Meas. Control, Trans. ASME, 107 (3), pp 220-226 (Sept 1985) 15 figs, 5 refs

KEY WORDS: Pumps, Pistons, Torque, Equations of motion

As part of a study involving methods of control of an axial piston pump, it is required to obtain linear or linearized equations of motion of the system's states. The torque imposed on the plate by the pumping action of the pistons is the most important term in the equation of motion of the swashplate. Mathematical equations describing swashplate torque are derived from general hydraulic and mechanical considerations given in this paper. Results of predictions made by the model are presented and compared with some experimental data provided by Sundstrand. An indication is also given as to changed in torque resulting from variation in swashplate angular velocity and timing position of the valve plate.

POWER TRANSMISSION SYSTEMS

86-948
Analysis of Three-Dimensional Cutting Process Dynamics
X.G. Yang, K.F. Eman, S.M. Wu
Univ. of Wisconsin-Madison, Madison, WI
J. Engrg. Indus., Trans. ASME, 107 (4), pp 336-342 (Nov 1985) 6 figs, 17 refs

KEY WORDS: Cutting

A new experimental method for three-dimensional cutting analysis based on times series models and the Dynamic Data System Methodology is introduced. Its theoretical formulation allows the treatment of both orthogonal and three-dimensional cutting without any additional complexity. Furthermore, it facilitates an easy explanation and proof of the independent of the inner and outer modulation effects and the use of a simple experimental setup. It is shown that the overall transfer matrix of the three-dimensional cutting process relating the force and relative displacement components can be identified in a single experiment. Based on the proposed theoretical models of the cutting process, experimental procedures and methods were proposed and used in actual cutting. The obtained results confirmed the theoretical expectations.

86-949
An Integrated Machining Process Design Simulator for the Optimal Design of Face Milling Systems
S.J. Lee, S.G. Kapoor, R.E. DeVor
Univ. of Illinois, Urbana, IL
J. Engrg. Indus., Trans. ASME, 107 (4), pp 301-308 (Nov 1985) 6 figs, 4 tables, 24 refs

KEY WORDS: Machining, Simulation

An Integrated Machining Process Design Simulator is developed and applied as a general tool for the design of face milling systems. The simulator includes four modules to accommodate the important factors that affect face milling operations. The design variables, constraints, and objective function of the entire system include structural element size, shape, and weight, cutting forces and vibrations. Machinability measure including tool life, metal removal rate, and surface finish are given. Several examples are included to demonstrate the capability.

MATERIALS HANDLING EQUIPMENT

86-950
Modeling and Control of a Rotary Crane
Y. Sakawa, A. Nakazumi
Osaka Univ., Toyonaka, Osaka, Japan
J. Dynam. Syst., Meas. Control, Trans. ASME, 107 (3), pp 200-206 (Sept 1985) 6 figs, 5 refs

KEY WORDS: Cranes (hoists), Mathematical models

In this paper a dynamical model for the control of a rotary crane, which makes three kinds of motion simultaneously is derived. The results of computer simulation prove that the open-loop plus feedback control scheme works well.

STRUCTURAL SYSTEMS

BRIDGES

86-951
Ambient Vibration Studies of Golden Gate Bridge: I. Suspended Structure
A.M. Abdel-Ghaffar, R.H. Scanlan
Princeton Univ., Princeton, NJ
ASCE J. Engrg. Mech., 111 (4), pp 463-482 (Apr 1985) 12 figs, 10 tables, 10 refs

KEY WORDS: Suspension bridges, Experimental data

Extensive experimental investigations were conducted on the Golden Gate Bridge in San Francisco, California, to deter nine, using ambient vibration data, parameters of major interest in both wind and earthquake problems, such as effective damping, the three-dimensional mode shapes, and the associated frequencies of the bridge vibration. The paper deals with the tests that involved the simultaneous measurement of vertical, lateral, and longitudinal vibration of the suspended structure; a subsequent paper addresses the measurement of tower vibration. Measurements were made at selected points on different cross sections of the stiffening structure: 12 were on the main span and 6 on the sidespan. Goodmodal identificationwas achieved by special deployment and orientation of the motion-sensing accelerometers and by summing and subtracting records to identify and enhance vertical, torsional, lateral, and longitudinal vibrational modes. In all, 91 modal frequencies and modal displacement shapes of the suspended span were recovered: 20 vertical, 18 torsional, 33 lateral, and 20 longitudinal, all in the frequency range 0.0-1.5 Hz. These numbers include symmetric and antisymmetric modes of vibration. Finally, comparison with previously computed two- and three-dimensional mode shapes and frequencies shows good agreement with the experimental results, thus confirming both the accuracy of the experimental determination and the reliability of the methods of computation.

86-952
Ambient Vibration Studies of Golden Gate Bridge: II. Pier-Tower Structure
A.M. Abdel-Ghaffar, R.H. Scanlan
Princeton Univ., Princeton, NJ
ASCE J. Engrg. Mech., 111 (4), pp 483-499 (Apr 1985) 15 figs, 6 tables, 9 refs

KEY WORDS: Suspension bridges, Damping coefficients, Experimental data

Dynamic characteristics such as natural frequencies, mode shapes, and damping ratios of the Golden Gate Bridge tower were determined using ambient vibration data. The ambient vibration tests involved the simultaneous measurement of longitudinal and lateral vibrations of the main tower. Measurements were made at different elevations of the tower and on the pier, at a total of 10 stations.

86-953
Analysis of the Observed Earthquake Response of a Multiple Span Bridge
J.C. Wilson
California Inst. of Tech., Pasadena
Rept. No. EERL-84-1, 171 pp (1984) PB85-240505/GAR

KEY WORDS: Bridges, Seismic response, Time domain method

The structure studies, the San Juan Bautista 156/101 Separation Bridge, is typical of many highway bridges in seismic regions of the United States. A time-domain technique of system identification is used to determine linear models which can closely replicate the observed bridge response. A three-dimensional finite element model which includes soil-structure interaction predicts several important features of the dynamic response of the bridge.

BUILDINGS

86-954
Alternative Reference Curves for Evaluation of the Impact Sound Insulation Between Dwellings
K. Bodlund
National Testing Institute, Borås, Sweden
J. Sound Vib., 102 (3), pp 381-402 (Oct 8, 1985) 13 figs, 21 refs

KEY WORDS: Buildings, Acoustic insulation

A survey of the sound insulation between modern Swedish dwellings was made by the National Testing Institute in 1983. This survey comprised measurements and interviews with tenants in eight housing areas. A discussion about how to measure and evaluate the impact sound insulation of floors was published. A good correlation was revealed between the mean impact sound index (determined by ISO 140 and 717) and the corresponding subjective mean score of each housing area and party construction. There were also indications about how to improve the method of deriving the impact sound index.

86-955
Wind-Induced Fatigue on Low Metal Buildings
B.A. Lynn, T. Stathopoulos
Concordia Univ., Montreal, Canada
ASCE J. Struc. Engrg., 111 (4), pp 826-839 (Apr 1985) 8 figs, 13 refs

KEY WORDS: Buildings, Wind-induced excitation, Fatigue life

Presently, fatigue is not considered a critical design factor for low metal buildings exposed to severe wind storms. Fatigue, however, has been shown to be the only possible cause of several roof failures, which occurred during cyclones. A simple approach for the evaluation of wind-induced fatigue on low buildings is presented.

86-956
Control of Lateral-Torsional Motion of Wind-Excited Buildings
B. Samali, J.N. Yang, C.T. Yeh
George Washington Univ., Washington, DC
ASCE J. Engrg. Mech., 111 (6), pp 777-796 (June 1985) 13 figs, 1 table, 26 refs

KEY WORDS: Multistory buildings, Wind-induced excitation, Turbulence, Active damping

An investigation is made of the possible application of an active mass damper control system to tall buildings excited by strong wind turbulence. The effectiveness of active control system, as measured by the reduction of the coupled lateral-torsional motion of tall buildings is studied. The wind turbulence is modeled as a stochastic process that is stationary in time but non-homogeneous in space. A numerical example of a forty-story building under strong wind excitations is given to illustrate the significant reduction of the building acceleration response by use of an active mass damper control system.

86-957
Dynamic Response of Tall Building to Wind Excitation
M.A.M. Torkamani, E. Pramono
Univ. of Pittsburgh, Pittsburgh, PA
ASCE J. Struc. Engrg., 111 (4), pp 805-825 (Apr 1985) 7 figs, 16 refs

KEY WORDS: Buildings, Wind-induced excitation, Torsional response

This paper investigates the dynamic responses of tall buildings subject to wind loading. One of the objectives of this research is to study the importance of the torsional dynamic response, coupled with translational responses. Finite element modeling is used to assemble the stiffness matrix of the structure. Torsional degrees of freedom are considered in the stiffness formulation of elements and systems. Aerodynamic forces on a tall building are calculated assuming a deterministic, pseudo-turbulent approach. These aero-dynamic forces are distributed over the height of the building. The equivalent concentrated aerodynamic loads, acting at each floor level are calculated using the principle of virtual displacements. One comparative study has been made between the finite element model and an equivalent continuous cantilever beam model. A second comparative study is between nonlinear and linear models. The results are presented as response spectra for different gust frequencies.

86-958
Torsional Instability in Hysteretic Structures
O.A. Pekau, P.K. Syamal
Concordia Univ., Montreal, Quebec, Canada
ASCE J. Engrg. Mech., 111 (4), pp 512-528 (Apr 1985) 11 figs, 12 refs

KEY WORDS: Buildings, Hysteretic damping, Torsional response, Seismic excitation

The occurrence of inelastic instability in the response of idealized eccentric building structures exhibiting various forms of bilinear hysteretic behavior is investigated. The Kryloff-Bogoliuboff method of averaging provides the response to harmonic ground excitation, with results examined in amplitude-frequency parameter space.

86-959
System Identification of Hysteretic Structures
A.O. Cifuentes
California Inst. of Tech., Pasadena, CA
Rept. No. EERL-84-4, 170 pp (1985) PB85-240489/GAR

KEY WORDS: Buildings, Hysteretic damping, Reinforced concrete, Seismic response, System identification techniques

The thesis is concerned with the earthquake response of hysteretic structures subjected to strong ground acceleration. Several earthquake records corresponding to different instrumented buildings are analyzed. Based on these observations, a new model for the dynamic behavior of reinforced concrete buildings is proposed. In addition, a suitable system identification algorithm to be used with this new model is introduced.

As a consequence, the new algorithm exhibits significant advantages from a computational point of view. Some numerical examples using actual earthquake data are discussed.

86-960
Seismic Damage Analysis of Reinforced Concrete Buildings
Young-Ji Park, A.H.-S. Ang, Yi Kwei Wen
Univ. of Illinois, Champaign-Urbana, IL
ASCE J. Struc. Engrg., 111 (4), pp 740-757 (Apr 1985) 13 figs, 1 table, 30 refs

KEY WORDS: Buildings, Reinforced concrete, Seismic response

A method for evaluating structural damage of reinforced concrete buildings under random earthquake excitations is proposed. Extensive damage analysis of SDF systems and typical MDF reinforced concrete buildings were performed. On the basis of these results, a simple relationship between the destructiveness of the ground motions, expressed in terms of the "characteristic intensity," and the structural damage, expressed in terms of the "damage index," is established. Reinforced concrete buildings that were damaged during past earthquakes were used to calibrate the proposed damage measure; on this basis, practical limits of structural damage are defined.

86-961
Mechanistic Seismic Damage Model for Reinforced Concrete
Young-Ji Park, A.H.-S. Ang
Univ. of Illinois, Champaign-Urbana, IL
ASCE J. Struc. Engrg., 111 (4), pp 722-739 (Apr 1985) 19 figs, 31 refs

KEY WORDS: Buildings, Reinforced concrete, Seismic design

A model for evaluating structural damage in reinforced concrete structures under earthquake ground motions is proposed. Damage is expressed as a linear function of the maximum deformation and the effect of repeated cyclic loading. Available static (monotonic) and dynamic (cyclic) test data were analyzed to evaluate the statistics of the appropriate parameters of the proposed damage model. The uncertainty in the ultimate structural capacity was also examined.

86-962
Simplified Earthquake Analysis of Structures with Foundation Uplift
A.K. Chopra, S.C.-S. Yim
ASCE J. Struc. Engrg., 111 (4), pp 906-930 (Apr 1985) 12 figs, 6 refs

KEY WORDS: Buildings, Seismic response

Simplified analysis procedures are developed to consider the beneficial effects of foundation-mat uplift in computing the earthquake response of structures. They respond essentially as single-degree-of-freedom systems in their fixed-base condition. These analysis procedures are presented for structures attached to a rigid foundation mat. It is supported on rigid foundation soil or flexible foundation soil modeled as two spring-damper elements. Winkler foundation with distributed spring-damper elements, or a viscoelastic half-space. In these analysis procedures, the maximum earthquake-induced base shear and deformation of an uplifting structure are computed directly from the earthquake response spectrum. It is demonstrated that the simplified analysis procedures provide results for the maximum base shear and deformation to a useful degree of accuracy for practical structural design.

TOWERS

86-963
Seismic Response of Pile Supported Cooling Towers
Bor-Jen Lee, P.L. Gould
Sargent & Lundy, Chicago, IL
ASCE J. Struc. Engrg., 111 (9), pp 1930-1947 (Sept 1985) 16 figs, 4 tables, 15 refs

KEY WORDS: Cooling towers, Shells, Seismic response, Pile structures, Soil-structure interaction

An analytical method is developed to determine the seismic response of rotational shell structures. Cooling towers, supported by deep foundations in the form of long piles are considered. The substructure deletion method is employed through the development of a dynamic boundary system at the contact area between the superstructure and the substructure. A new mathematical formulation compatible with the shell deformation is developed to deal with the rigid body motions due to the negation of the fixed base assumption. Two pile foundation cases are

considered in order to examine the effect of soil-pile-structure interaction on the seismic response of cooling towers.

FOUNDATIONS

86-964

Simple Model for Transient Soil Loading in Earthquake Analysis. II. Non-Associative Models for Sands

M. Pastor, O.C. Zienkiewicz, K.H. Leung
Univ. of Wales, Swansea, UK

Intl. J. Numer. Anal. Methods Geomech., 9 (5), pp 477-498 (Sept/Oct 1985) 18 figs, 1 table, 45 refs

KEY WORDS: Sand, Soils, Seismic analysis, Cyclic loading

This paper extends the bounding surface, generalized plasticity and models to reproduce the behavior of sands under both static and transient loading.

86-965

New Elements Regarding the Definition of Spring Constants and the Elastic Coefficients of the Foundation — Soil Interaction

Gh. Buzdugan, I. Mincă
Polytechnic Institute of Bucharest, Romania

Dynamics of Machine Foundations, Proc. of Symp. Bucharest, Romania, pp 111-125 (Oct 22-24, 1985), 4 figs, 4 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Soil-foundation interaction, Elastic properties, Spring constants

The paper outlines the indirect dependence between the horizontal elastic force and the rocking elastic couple on one side, and the foundation base rotation and its horizontal translation on the other side. The elastic constants are defined as well as the elastic coefficients corresponding to this elastic coupling of the effects of horizontal translation (sliding) and rocking. At the same time, the paper presents new concepts regarding the definition of the elastic coefficients of uniform compression and uniform sliding to make them independent on the contact conditions between foundation and soil.

86-966

Vibrations in Nonlinear Viscoelastic Soils

D. Bratosin, I. Vasile
Center of Earth Physics and Seismology, Bucharest, Romania

Dynamics of Mach. Foundations, Proc. of Symp. Bucharest, Romania, pp 89-96 (Oct 22-24, 1985) 3 figs, 2 tables, 4 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Soils, Viscoelastic media, Harmonic excitation, Resonant column tests

Considering soils as nonlinear visco-elastic materials subject to harmonic strain histories, analytic forms for the strain dependence of the dynamic moduli and damping of soils are obtained. The parameters of these functions are obtained from resonant column tests.

86-967

Dynamic Parameters of Soils by the Resonant Column Method

Gh. Mărmreanu, F. St. Balan, E. Cojocaru
Center of Earth Physics and Seismology, Bucharest, Romania

Dynamics of Machine Foundations, Proc. of Symp. Bucharest, Romania, pp 127-134, (Oct 22-24, 1985) 5 figs, 3 refs, AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Soils, Resonant column tests, Machinery induced vibrations, Seismic excitations

The resonant column method and the basic principles for computing shear, longitudinal (Young) elastic moduli and damping characteristics of soils in function of deformation state induced during machine vibrations and strong earthquake environments are considered. The strong nonlinearity dependence between dynamic parameters of soils and deformation state is emphasized.

86-968

Comparative Response of Alluvium to Hopkinson Bar and Gas Gun Loading

E.S. Gaffney, J.A. Brown
Los Alamos National Lab., NM

Rept. No. LA-UR-85-2287, CONF-850736-9, 7 pp (1985) 5 refs, 6 figs, DE85014068/GAR

KEY WORDS: Soils, Dynamic tests, underground structures, Explosion effects

Standard explosive techniques used for dynamic testing of highly dispersive media materials do not produce data under conditions relevant to most real applications. Techniques for testing soils dynamically at strain rates ranging from about 10 exp 2 to about 10 exp 4 sec exp-1 in uniaxial strain using a Hopkinson Bar have been developed. This admits direct comparison with data from gas gun tests where strain rates are in the range of 10 exp 4 to 10 exp 5 sec exp-1. This, in turn, permits the separation of inertial effects from direct strain-rate effects. In order to assist in evaluation of the results we have also developed a one dimensional microphysical model of soil.

86-969

Experimental Values of the Dynamic Coefficients of Subgrade Reaction

Gh. Buzdugan, I. Mincă
Polytechnic Institute of Bucharest, Romania
Dynamics of Mach. Foundations, Proc. Symp. Bucharest, Romania, pp 97-109 (Oct 22-24, 1985) 2 figs, 3 tables, 7 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Machine foundations, Vibration tests, Test equipment, Testing techniques, Soil-foundation interaction

In vibration computation of large machine foundations, placed directly on the ground, it is often preferred to use the dynamic coefficients of subgrade reaction measured in-situ by forced vibration tests on model foolings. The paper presents the equipment designed to this purpose. The testing methodology, as well as a synthesis of the results obtained during the last decade, are presented.

86-970

Random Vibration of Machine Foundations

D. Makovička
Czech Technical University, Prague, CSSR
Dynamics of Mach. Foundations, Proc. of Symp. Bucharest, Romania, pp 49-60 (Oct 22-24, 1985) 6 figs, 4 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Machine foundations, Natural frequencies, Time dependent parameters

The stochastic solution of free and forced vibration of machine foundations enables to determine the variation of the response characteristics. The paper deals with the calculation of the eigenfrequencies and time dependent displacements of the system with random variable mass and stiffness parameters. The purpose of the study was the determination of the probability of occurence of the vibration parameters.

86-971

Soil-Structure Interaction Effects on Dynamic Characteristics of Machine Foundations

M. Ifrim, F. Macavei, S. Demetriu, I. Vlad
Civil Engineering Institute, Bucharest, Romania
Dynamics of Mach. Foundations, Proc. of Symp. Bucharest, Romania, pp 35-44 (Oct 22-24, 1985) 5 figs, 4 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Machine foundations, Soil-structure interaction

Foundations soil properties are an important factor in dynamic analysis and design of foundation-machine system. In the paper a comparative study is performed concerning the effects of elastic properties of soil on vibration eigenmodes. An analysis of some elastic support members (isolators) on proper dynamic characteristics of the system is also performed.

86-972

Basic Concepts Governing the Romanian Code of Practice for Machine Foundation Design

V.I. Apostolescu
Institute for Nuclear Power Reactors, IRNE, Bucharest, Romania
Dynamics of Mach. Foundations, Proc. of Symp. Bucharest, Romania, pp 17-26 (Oct 22-24, 1985) 2 figs, 14 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Machine foundations, Design techniques, Standards and codes

Both theoretical concepts and their consequences for practical design are discussed. Emphasis lies on consistency of the code with the Limit States structural design method as practiced for static loads throughout Romania. Some original features incorporated in the code are outlined and commented.

86-973
On the Possibility of Tuning the Foundation-Machine Assembly
M. Păunescu, V. Butuman
Polytechnic Institute "Traian Vuia", Timişoara
Dynamics of Mach. Foundations, Proc. of Symp. Bucharest, Romania, pp 135-144 (Oct 22-24, 1985) 7 figs, 1 table, 7 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti Romania

KEY WORDS: Machine foundations, Elastomers, Vibration isolators, Tuning

The work deals with a new improved technology used for difficult foundation soils, that can also be applied for machine-foundations. By means of this technology, superior elastic and bearing capacities are reached by foundation soils.

86-974
New Aspects Regarding the Design of Machine Foundations
D. Weiner
Dynamics of Mach. Foundations, Proc. of Symp. Bucharest, Romania, pp 73-88 (Oct 22-24, 1985) 5 figs, 10 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Machine foundations, Expansion Joints

Conventional expansion joints have long been used to combat vibrations in the surroundings. They can have the opposite effect to normal experience, this is shown in this paper. It presents new aspects regarding the design of foundations for machines generating horizontal dynamic forces.

86-975
Some Considerations on the Choice of Foundation Systems Aimed to Reduce the Dynamic Effects in Case of Wide-Band Spectrum Actions
H. Sandi
Building Research Institute - INCERC, Bucharest, Romania
Dynamics of Machine Foundations, Proc. of Symp. Bucharest, Romania, pp 61-71 (Oct 22-24, 1985) 2 figs, 6 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Machine foundations, Shakers, Earthquake simulation

The paper is intended to contribute to the appropriate choice of foundation systems aimed to reduce the dynamic effects in case of wide-band spectrum actions. A typical example is foundations for large shaking tables intended to simulate seismic motions. The main technical criteria to be considered in this field are discussed. Some specific features of the case of wide-band spectrum disturbances are considered. Some basic relations concerning the oscillations of foundation blocks are presented.

86-976
Coefficients of Elasticity for Improving the Soil by Ballast Plots, Determined in Situ
P. Marin, J. Avram, L. Eugen
Polytechnical Institute "Trian Vuia", Timişoara
Dynamics of Mach. Foundations, Proc. of Symp. Bucharest Romania, pp 145-152 (Oct 22-24, 1985) 4 figs, 1 table, 8 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Machine foundations, Elastic properties

This paper points out an improved solution of a weak foundation soil with ballast plots for the foundation execution of two compressors. Vibration measurements were done in the improved terrain in order to determine the coefficients of elasticity.

86-977
Elastic and Inertial Modelling of Reinforced Concrete-Frame Machine Foundations for Turbogenerators and Turbocompressors
M. Ifrim, F. Macavei
Civil Engineering Institute, Bucharest, Romania
Dynamics of Mach. Foundations, Proc. Symp. Bucharest, Romania, pp 225-236 (Oct 22-24,

1985) 6 figs, 2 tables, 8 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Machine foundations, Concrete, Turbomachinery, Natural frequencies, Mathematical models

Vibration eigenmodes synthetically characterize the structure from the dynamic point of view. They depend on the elastic and inertial characteristics of the machine foundation. Significant eigenmodes, necessary for the analysis, are specified by action and response.

86-978
The Effect of Design Parameters on Forced Oscillations of Turbogenerator Supports (Einfluß von Konstruktionsparametern auf die erzwungenen Schwingungen von Turbogenerator-ständern)
D. Albrecht, W. Krause, W.-D. Krüger
Ingeniewchochschule Zittau, German Dem. Rep.
Maschinenbautechnik, Berlin 34 (6), pp 271-272 (June 1985) 5 figs, 1 table, 1 bibl (in German)

KEY WORDS: Turbogenerators

Safe operation of turbogenerators requires a precise knowledge of turbogenerator support vibration response. Using a double plate model of a generator support, forced vibration amplitudes of the laminated sheet plate and an elastic housing are calculated.

86-979
Modelling of Turbo Foundations for Dynamic and Static Analysis Using Finite Element Programs
V.I. Mastată, I.Al. Sântu
Institute for Power Studies and Designs, Bucharest, Romania
Dynamics of Mach. Foundations, Proc. Symp. Bucharest, Romania, pp 269-278 (Oct 22-24, 1985) 3 figs, 1 ref. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Turbogenerators, Machine foundations, Finite element technique, Seismic design

When analyzing structures by means of programs based on the finite element method, model selection is essential for appropriate quality results. In the present paper the authors make a synthesis of the conclusions drawn from their own modeling activity in connection with static and dynamic design of turbine-generator foundations.

86-980
Why the Spring-Supported Foundations are the Best Ones for the Skoda Turbosets
R. Masopurt, M. David
Energoprojekt, Prague, Czechoslovakia
Dynamics of Mach. Foundations, Proc. Symp. Bucharest, Romania, pp 257-268 (Oct 22-24, 1985) 8 figs, 8 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Turbomachinery, Machine foundations, Spring-supported foundations, Vibration isolation

The main dynamic advantages of the spring-supported foundations for the Skoda steam turbosets are briefly described and illustrated.

86-981
Turbine Foundation with Spring-Supported Upper Plate Using Vertical Adjustment Devices
S. Tatomir, D. Chitu
Power Studies and Design Institute, Bucharest, Romania
Dynamics of Mach. Foundations, Proc. Symp. Bucharest, Romania, pp 279-285 (Oct 22-24, 1985) 3 figs, 5 refs. AVAIL: Institutul Politehnic Bucuresti, Catedre de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Turbomachinery, Machine foundations, Concrete, Spring-supported foundations

The authors present a foundation solution with a stiff reinforced concrete upper-plate resting on springs and having also vertical adjustment devices to control horizontality for 50 MW turbo-sets of the DSL-50 and DKU-50 types.

HARBORS AND DAMS

86-982
Simplified Earthquake Analysis of Concrete Gravity Dams: Combined Hydrodynamic and Foundation Interaction Effects
G. Fenves, A.K. Chopra

Univ. of Texas, Austin, TX
ASCE J. Engrg. Mech., 111 (6), pp 736-756 (June 1985) 8 figs, 10 refs

KEY WORDS: Dams, Seismic analysis

A companion paper presented simplified procedures for earthquake analysis of the fundamental mode response of concrete gravity dams. Separate effects of dam-foundation rock interaction and dam-water interaction with reservoir bottom absorption were included. These procedures are extended to develop a simplified analytical procedure for evaluation of the response of concrete gravity dams to earthquake ground motion. The simultaneous effects of dam-water interaction, reservoir bottom absorption, and dam-foundation rock interaction were included. Expressions for the parameters of an equivalent SDF system that models the fundamental mode response of dams are derived. A procedure to implement the analytical procedure is outlined, and an extension to consider the response contributions of the higher vibration modes of the dam is briefly mentioned.

86-983
Simplified Earthquake Analysis of Concrete Gravity Dams: Separate Hydrodynamic and Foundation Interaction Effects
G. Fenves, A.K. Chopra
Univ. of Texas, Austin, TX
ASCE J. Engrg. Mech., 111 (6), pp 715-735 (June 1985) 12 figs, 20 refs

KEY WORDS: Dams, Seismic analysis

Simplified procedures are presented for the analysis of the fundamental vibration mode response of concrete gravity dam systems are given. Dams with reservoirs of impounded water supported on rigid foundation rock and dams with empty reservoirs supported on flexible foundation rock are included.

86-984
Nonlinear Hysteretic Dynamic Response of Soil Systems
J.-H. Prevost, A.M. Abdel-Ghaffar, A.-W. M. Elgamal
Princeton Univ., Princeton, NJ
ASCE J. Engrg. Mech., 111 (5), pp 696-713 (May 1985) 13 figs, 28 refs

KEY WORDS: Dams, Hysteretic damping

A simplified analysis procedure for the nonlinear hysteretic dynamic response of soil or structural systems, or both, is presented. The method is based on a Galerkin formulation of the equations of motion in which the solution is expanded using basis functions defined over the spatial domain occupied by the soil system.

CONSTRUCTION EQUIPMENT

86-985
Determination of Resonat Weights (Zur Problematik der Bestimmung Mitschwingender Massen)
W. Arnold
Technische Hochschule Otto von Guericke, Magdeburg
Maschinenbautechnik, 34 (4), pp 170-173 (1985) 6 figs, 13 refs (in German)

KEY WORDS: Compaction equipment, Resonant response

The size of resonating weights, needed for the determination of the effect of vibration material on the dynamic response of compaction equipment is obtained using a vertically excited vibration table. Vibrating material is idealized as a Voigt body. From these results, the possibilities and limitation to calculate the dynamic response from the resonant weights are obtained.

POWER PLANTS

86-986
Model Predictions of Dynamic Instablity Threshold for Boiling Flow Systems
R.P. Roy, R.C. Dykhuizen, D.M. France, S.P. Kalra
Arizona State Univ., Tempe, AZ
(Annual Meeting of the American Nuclear Soc., Boston, MA, Jun 9, 1985) Rept. No. CONF-850610-17, 7 pp (Dec 1984) DE85006833/GAR

KEY WORDS: Nuclear reactors, Fluid-induced excitation, Frequency domain method, Time domain method

Boiling flow systems such as boiling water nuclear reactors and once-through steam generators may be susceptible to dynamic instabilities of various types. The most common among these is a low frequency (0.1 to 2 Hz, typically) oscilla-

tory flow instability of the limit-cycle type termed "density-wave oscillations (DWO)". In the present paper, two different computer models have been used to predict DWO threshold power input for various operating conditions of an experimental system which features an electrically-heated test section assembly and wateras the experimental system which features an electrically-heated test section assembly and water as the experimental fluid. One of the models, a frequency-domain model, has been in use for quite some time in the nuclear industry. The other is an improved version of a time-domain two-fluid model proposed by us recently.

86-987

Experimental and Analytical Study on Buckling of Fluid-Coupled Structures During a Seismic Load

B. Barthelet, P. Geoffroy, A. Combescure
CEA Centre d'Etudes Nucleaires de Saclay, Gif-sur Yvette, France
(ASME Pressure Vessel and Piping Conf., San Antonio, TX, Jun 17, 1984) Rept. No. CEA-CONF-7327, CONF-840647-34, 15 pp (Jun 1984) DE85/51099/GAR

KEY WORDS: Nuclear reactors, Seismic analysis

Seismic analysis of liquid metal fast breeder reactor is generally made with a linear dynamic model.

86-988

DYNA3D, INGRID, and TAURUS: An Integrated, Interactive Software System for Crashworthiness Engineering

D.J. Benson, J.O. Hallquist, D.W. Stillman
Lawrence Livermore National Lab., CA
(ASME Intl. Computers in Engrg. Conf. and Exhibition, Boston, MA, Aug 4, 1985) Rept. No. UCRL-92218, CONF-850862-2, 9 pp (Apr 1985) DE85010928/GAR

KEY WORDS: Crashworthiness, Nuclear fuel elements, Radioactive materials, Transportation effects, Computer programs

An integrated, interactive set of finite element programs for crashworthiness analysis have been developed. The heart of the system is DYNA3D, an explicit, fully vectorized, large deformation structural dynamics code. DYNA3D has the following four capabilities that are critical for the efficient and accurate analysis of crashes. Fully nonlinear solid, shell, and beam elements for representing a structure and a broad range of constitutive models for representing the materials are included. Sophisticated contact algorithms for the impact interactions, and a rigid body capability to represent the bodies away from the impact zones at a greatly reduced cost without sacrificing any accuracy in the momentum calculations are also included.

86-989

Handbook of Nuclear Power Plant Seismic Fragilities: Seismic Safety Margins Research Program

L.E. Cover, M.P. Bohn, R.D. Campbell, D.A. Wesley
Lawrence Livermore National Lab., CA
Rept. No. UCRL-53455, 324 pp (Jun 1985) NUREG/CR-3558/GAR

KEY WORDS: Nuclear power plants, Nuclear reaction safety, Seismic response

The goal of the Seismic Safety Margins Research Program is to develop a complete and fully-coupled analysis procedure, including methods and computer codes, for estimating the risk of earthquake-induced radioactive release from a commercial nuclear power plant. As part of this program, calculations of the seismic risk from a typical commercial nuclear reactor were made. The report describes the development of the required fragility relations and the data sources and data reduction techniques upon which they are based. Both building and component fragilities are covered.

86-990

Flow-Induced Vibration: Guidelines for Design, Diagnosis, and Troubleshooting of Common Power Plant Components

M.K. Au-Yang
Babcock & Wilcox, Lynchburg, VA
J. Pressure Vessel Tech., Trans. ASME, 107 (4), pp 326-334 (Nov 1985) 3 figs, 41 refs

KEY WORDS: Power plants, Fluid-induced excitation, Monitoring techniques, Diagnostic techniques

The different techniques of assessing the flow-induced vibration problems of common power plant components are reviewed. The components are divided into categories of single cylinders,

flat plates, pipes containing flowing fluid, cylindrical shells, and the tube banks. The mechanisms considered included turbulent buffeting, instability, vortex shedding, acoustics, and leakage flow-induced vibrations. Emphasis is placed on applications to industrial problems.

VEHICLE SYSTEMS

GROUND VEHICLES

86-991
Aerodynamic Forces on Motor Vehicles. 1970-July 1985 (Citations from the NTIS Data Base)
NTIS, Springfield, VA
165 pp (July 1985) PB85-864601/GAR

KEY WORDS: Ground vehicles, Aerodynamic loads, Bibliographies

This bibliography contains citations concerning aerodynamic lift, drag, and side forces exerted on moving motor vehicles. Included are forces generated on moving motor vehicles by other vehicles, as in a passing or heavy traffic situation. Many of the cited references pertain to drag reduction techniques. Aerodynamic forces that are investigated include those exerted on the vehicle body, suspension system, steering and roadability factors, and on air inlets for the engine. (This updated bibliography contains 177 citations, 38 of which are new entries to the previous edition.)

86-992
Dynamics of Steel Elevated Guideways — An Overview
Subcommittee on Vibration Problems Associated with Flexural Members on Transit Systems, Committee on Flexural Members of the Committee on the Metals of the Stuctural Division
ASCE J. Struc. Engrg., 111 (9), pp 1873-1898 (Sept 1985) 6 figs, 10 tables, 89 refs

KEY WORDS: Guideways, Reviews

The most significant advances over the last 15 years relative to the dynamic problems of aerial guideways are summarized. Emphasized are guideways with steel supporting flexural members, designed for the exclusive right-of-way of a particular type of vehicle. Steel wheel-on-rail, rubber tire, or air-levitated vehicles are considered. Nondimensional parameters characterizing guideway-vehicle interactions are catalogues and related to recent designs and current design practice.

SHIPS

86-993
Ductile Fracture of Dynamically Loaded Naval Structures — Compact Tension Specimen Tests and Analyses
E.A. Rasmussen, W.E. Carr, L.N. Gifford
David W. Taylor Naval Ship Res. and Dev. Ctr., Bethesda, MD
Rept No. DTNSRDC/84/071, 147 pp (Feb 1985) AD-A155 472/4/GAR

KEY WORDS: Ships, Fracture properties

A combined experimental/analytical research program aimed at extending the static J-integral to the case of dynamic inelastic fracture is described. This program was a first step toward the goal of quantifying the fracture response of naval structures containing flaws subjected to dynamic loading. One-inch thick HY-80 baseplate was used because of its known toughness and its widespread application in naval structures. For the experimental work, a drop weight test fixture was designed that permitted controllable, high rate loading of precracked compact tension specimens. A series of specimens was tested, and applied load, load point displacements, and back face strains were routinely measured. For the analytical work, two-dimensional finite element analyses were performed in conjunction with the experiments in an effort to further develop analytical techniques for dynamic fracture problems. The analyses performed displayed variable correlation with the experimental results.

AIRCRAFT

86-994
Acoustic Intensity Techniques for Airplane Cabin Applications
G.A. Dalan, R.L. Cohen

Boeing Commercial Airplane Co., Seattle, WA
J. Aircraft, 22 (10), pp 910-914 (Oct 1985) 8 figs, 1 table, 12 refs

KEY WORDS: Aircraft, Interior noise, Noise source identification, Acoustic intensity method, Two microphone technique

A technique to measure surface radiation from an airplane cabin in flight using a two-microphone acoustic intensity system is described. The technique addresses the problems of high background levels and surface absorption that have in the past complicated cabin radiation measurements. A bare probe for the reflective sidewall and ceiling regions and a shielded probe for the absorptive carpet were used. Laboratory tests were conducted to establish the accuracy and tolerance to background noise for the flight measurement system. From these tests the operating range for each probe was determined in terms of the difference in sound pressure and intensity levels. This difference, called the signal-to-noise indicator, was used to screen out flight data saturated by the background field. From the cabin surveys, several strong radiation areas, such as the ceiling panel and the air distribution and air return grills, were measured quantitatively. Small area sources were distinguished from adjacent areas, and other weak sources were identified.

86-995
Verification of Calculation Methods for Unsteady Airloads in the Prediction of Transonic Flutter
R.J. Zwaan
National Aerospace Lab., Amsterdam, the Netherlands
J. Aircraft, 22 (10), pp 833-839 (Oct 1985) 15 figs, 15 refs

KEY WORDS: Aircraft wings, Flutter

Various engineering-type methods to calculate unsteady airloads on wings in transonic flow were applied in flutter calculations for a semispan flutter model of a supercritical wing. Verification was performed on the basis of comparing flutter characteristics, in which special attention was given to the prediction of transonic dips in the flutter boundaries. The methods were able to produce useful results when applied complementarily.

86-996
Integrated Damped Fuselage Structure
L.M. Butzel
Boeing Military Airplane Co., Seattle, WA
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp QQ-1 - QQ-30, AD-AA152 547) AD-P004 722/5/GAR

KEY WORDS: Aircraft, Viscoelastic damping, Design techniques

This presentation describes a program, aimed at developing design guidelines for viscoelastic damping applied to skin-stringer-frame type aerospace structure. Periodic structure type response models developed as a first part of the program are discussed. Two procedures for assigning values of the damping parameters required to these models are presented. Results of test efforts to develop and verify the damping parameter assignment procedure and response prediction model are also discussed.

86-997
Laminated Damped Fuselage Structures
R.A. Ely
LTV Aerospace and Defense Co., Dallas, TX
(Vibr. Damping Workshop Proc. Long Beach, CA, Feb 27-29, 1984, pp OO-1 -OO-33, AD-A152 547) AD-P004-720/9/GAR

KEY WORDS: Aircraft, Layered damping, Acoustic fatigue

This paper discusses the application of constrained layer damping, in the form of laminated skins, frames, and equipment racks, to control of acoustical fatigue of structures. Vibration of equipment in the aft fuselage sections of large aircraft is also covered. Discussions of applications of constrained layer damping go beyond conventional skin-stringer configurations to include honey-comb structures. It is shown that the influence of constrained layer damping on the response of a honeycomb panel at its critical frequency is very different from the influences on its resonant responses.

86-998
Application of CFD Techniques Toward the Validation of Nonlinear Aerodynamic Models
L.B. Schiff, J. Katz
NASA Ames Res. Ctr., Moffett Field, CA
Rept. No. REPT-85212, NASA-TM-86715, 18 pp (May 1985) (Presented AGARD Fluid Dyn. Panel

and Flight Mech. Panel Symp. on Unsteady Aerodyn: Fundamentals and Appl. to Aircraft Dyn., Gottingen, W. Germany, May 6-9, 1985) N85-26671/6/GAR

KEY WORDS: Aircraft, Aerodynamic loads, Mathematical models

Applications of computational fluid dynamics methods to determine the regimes of applicability of nonlinear models describing the unsteady aerodynamic responses to aircraft flight motions are described. The potential advantages of computational methods over experimental methods are discussed and the concepts underlying mathematical modeling are reviewed. The economic and conceptual advantages of the modeling procedure over coupled, simultaneous solutions of the gasdynamic equations and the vehicle's kinematic equations of motion are discussed. The modeling approach, when valid, eliminates the need for costly repetitive computation of flow field solutions. For the test cases considered, the aerodynamic modeling approach is shown to be valid.

86-999

Effects of Acoustic Treatment on the Interior Noise of a Twin-Engine Propeller Airplane

T.B. Beyer, C.A. Powell, E.F. Daniels, L.D. Pope
NASA Langley Research Center, Hampton, VA
J. Aircraft, 22 (9), pp 784-788 (Sept 1985) 12 figs, 1 table, 18 refs

KEY WORDS: Aircraft, Interior noise, Noise reduction

A study of the cabin acoustics of a Fairchild Merlin IVC twin-engine propeller airplane is described. The sound field was measured at six locations inside both an untreated "green" airplane and a completely finished airplane. Several flight conditions were tested, including different altitudes, engine power settings, and cabin pressures. The overall sound pressure level for each test conditions and microphone position was computed from a one-third octave band analysis of the data. The blade passage frequency and its integral multiples were examined using a narrowband analysis of the data. The insertion loss due to the added acoustical treatment was determined by comparing the narrowband results from the two airplanes. These insertion loss values varied widely, depending on the many factors, such as position in the cabin, multiple of blade passage frequency, cabin pressure, and engine torque. The space-averaged sound pressure levels corresponding to specific tests of the treated airplane were found to be in good agreement with predictions from the Propeller Aircraft Interior Noise (PAIN) computer program.

86-1000

Beam Dampers for Skin Vibration and Noise Reduction in the 747

R.N. Miles
Boeing Co., Seattle, WA
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp PP-1 -PP18, AD-A152 547) AD-P004 721/7/GAR

KEY WORDS: Dampers, Beams, Aircraft noise, Interior noise, Noise reduction

A special constrained layer damped has been incorporated into the Boeing 747 upper deck fuselage structure. This damper replaces a rivetted stiffener which was installed to reduce noise levels inside the cabin. It has been found that the damper installation produced a noise reduction equal to that achieved by the stiffener.

86-1001

Use of Skin Damping Treatments to Control Airframe Dynamic Response for Interior Noise Control

C.L. Holmer
Cabot Corp., Indianapolis, IN
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp RR-2 - RR-20, AD-A152 547) AD-P004 723/3/GAR

KEY WORDS: Material damping, Aircraft noise, Interior noise, Noise reduction

This paper defines the role of structural damping treatments applied to the skin of aircraft; develops some new materials for use in this particular application; and demonstrates the role of these materials in actual aircraft flight tests.

86-1002

Design Guide for Damping of Aerospace Structures

J. Soovere, M.L. Drake, V.R. Miller
Lockheed-California Co., Burbank, CA

(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp VV-1 -VV-10, AD-A152 547) AD-P004 727/4/GAR

KEY WORDS: Damping coefficients, Material damping, Design techniques, Viscoelastic damping, Aircraft

The effectiveness of polymeric damping materials in controlling resonant vibration problems has been established through many successful applications. The area of these applications range from aircraft structures to jet engine structures. An effort is underway to develop a viscoelastic damping design guide for use by designers. This paper provides a brief outline of this effort.

MISSILES AND SPACECRAFT

86-1003
Experiments Using Lattice Filters to Identify the Dynamics of a Flexible Beam
N. Sundararajan, R.C. Montgomery
NASA Langley Research Center, Hampton, VA
J. Dynam. Syst., Meas. Control, Trans. ASME, 107 (3), pp 187-191 (Sept 1985) 8 figs, 9 refs

KEY WORDS: Spacecraft, Parameter identification technique, Beams

An approach for identifying the dynamics of large space structures is applied to a free-free-beam. In this approach the system's order is determined on-line including mode shapes. Recursive lattice filters which provide a linear least square estimate of the measurement data are used. The mode shapes determined are orthonormal in the space of the measurements. Hence, the are not the natural modes of the structure. To determine the natural modes of the structure, a method based on the fast Fourier transform is used on the outputs of the lattice filter. These natural modes are used to obtain the modal amplitude time series from the measurements.

86-1004
Identification and Control of Structures in Space
L. Meirovitch, R.D. Quinn, M.A. Norris
Virginia Polytechnic Inst. and State Univ., Blacksburg, VA
Rept. No. NASA-CR-175790, 18 pp (1984) N85-26850/6/GAR

KEY WORDS: Spacecraft, Parameter identification technique, Vibration control

The derivation of the equations of motion for the Spacecraft Control Laboratory Experiment is reported. The equations of motion of a similar structure orbiting the earth are also derived. The structure is assumed to undergo large rigid-body maneuvers and small elastic deformations. A perturbation approach is proposed whereby the quantities defining the rigid body maneuver are assumed to be relatively large with the elastic deformations and deviations from the rigid-body maneuver being relatively small. The perturbation equations have the form of linear equations with time-dependent coefficients. An active control technique can then be formulated to permit maneuvering of the spacecraft and simultaneously suppressing the elastic vibration.

86-1005
Flexible Structure Control in the Frequency Domain
R. Harding, A. Das
General Electric Co., Philadelphia, PA
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp CCC-1 - CCC-21, AD-A152 547) AD-P004 733/2/GAR

KEY WORDS: Spacecraft, Modal damping, Frequency domain method

New techniques to analyze structure and controller interaction in the frequency domain are defined. They are used to determine the modal damping requirements of the spacecraft structure to assure control system stability and performance. Gain and phase versus frequency (Bode and Nyquist) techniques are described. They predict system stability in the presence of uncontrolled structural modes and errors in a priori natural frequencies and quantify control system margin for these modes. The techniques are applied to an optimally controlled single axis satellite with very large solar arrays. Control system actuator and sensor configurations are based upon system controllability and observability of four dominant structural modes. Verification of the technique is by simulation.

86-1006
Damping Application to Spacecraft
T.S. Nishimoto
Rockwell International, Seal Beach, CA

(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp SS-1 -SS-8, AD-A152 547), AD-P004 724/1/GAR

KEY WORDS: Spacecraft, Vibration damping, Design techniques

The purpose of this report is to present various cases of design application of camping technology to spacecraft development. These cases illustrate various vibration problems for which damping was used as a design tool. The relative success and difficulties encountered are presented. Damping technology in application to spacecraft addresses several design problem areas. Vibroacoustics environment associated with launch vehicle noise is an area of interest of long standing. On-orbit S/C controls problems have also emerged as candidates for damping technology. Problems associated with precision pointing and constrained settling time from controls reorientation are finding similar controls design solutions are damping concepts. The cases presented are a progression from smaller elements to system design applications.

86-1007
Structural Damping of Shuttle Orbiter and Ascent Vehicles
D.L. Jensen
Rockwell International, Downey, CA
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp Z-1 -Z-14, AD-A152 547) AD-P004 708/4/GAR

KEY WORDS: Space shuttles, Experimental modal analysis, Modal damping, Viscous damping, Coulomb friction

Experimental structural mode damping factor data are presented for an actual full size vehicle structure. These data were obtained from vibration test programs conducted during development of the shuttle orbiter vehicle. Results show average values of structural damping factor range from 0.017 to 0.032. Theoretical analysis indicates a primary source of energy dissipation due to air mass displacement is directly dependent on amplitude of motion. An analysis of frictional energy loss develops a relation between viscous damping factor and coulomb friction. The theoretical and analytical development provides a basis for understanding and interpreting the test results.

86-1008
Comparison of Measured Spacecraft Modal Damping Values
B.K. Wada, J.C. Chen
California Inst. of Tech., Pasadena, CA
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, PP Y-1 -Y-7, AD-A152 547) AD-P004 707/6/GAR

KEY WORDS: Spacecraft, Experimental modal analysis, Modal damping

The presentation summarized the experiences at the Jet Propulsion Laboratory in the prediction and the measurement of modal damping values of spacecraft for use in the determination of design loads. The initial recognition of the uncertainty in the prediction of damping and the direct dependence of damping on the design loads when subjected to slowly swept sinusoidal input resulted in an effort to use realistic transient forcing functions. Experiences in the solution of complex eigenvalue response solutions resulting from modal synthesis of subsystems, each subsystem assigned modal damping values, were also discussed. Damping data on both the Voyager and the Galileo spacecrafts using up to 8 different types of techniques to analyze modal data were presented. The preliminary conclusions are that difficulty exists in estimating the true damping of a structure and the measured damping values are dependent on the analysis method of the data. A large quantity of damping data is available.

86-1009
Concepts and Effects of Damping in Isolators
J. Kerley
NASA Goddard Space Flight Ctr., Greenbelt, MD
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp L-1 -L-15, AD-A152 547) AD-P004 695/3/GAR

KEY WORDS: Spacecraft, Damping effects, Design techniques

This paper presents a series of innovative designs and inventions that has led to the solution of many aerospace vibration and shock problems through damping techniques. In particular, the design of damped airborne structures has presented a need for such creative innovation. The primary concern has been to discover just what concepts were necessary for good structural damping. Once these concepts were determined and converted into basic principles, the design of hardware followed.

86-1010
Experimental Measurement of Material Damping for Space Structures
E.F. Crawley, R.L. Sheen

Massachusetts Inst. of Tech., Cambridge, MA (Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp F-1 -F-19, AD-A152 547) AD-P004 691/2/GAR

KEY WORDS: Spacecraft, Experimental modal analysis, Material damping

An experimental procedure for this measurement of material damping is described. In this procedure, the free decay of free-free beams, when lofted into free fall in a vacuum, is recorded and analyzed. Tests were performed on aluminum, graphite/epoxy, and graphite/magnesium metal matrix materials.

86-1011

Damping in Support Structures for Satellite Equipment Reliability — RELSAT (Reliability for Satellite Equipment in Environmental Vibration)

J.A. Staley, C.V. Stahle

General Electric Co., Philadelphia, PA

(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp UU-1 - UU-26, AD-A152 547) AD-P004 726/6/GAR

KEY WORDS: Spacecraft instrumentation responses, Launching, Spacecraft platforms, Vibration damping

This paper presents a discussion of the General Electric Reliability for Satellite Equipment in Environmental Vibration program. This program is sponsored by the Flight Dynamics Laboratory, Air Force Wright Aeronautical Laboratories. The need for and benefits from applying vibration during launch and ground vibration tests are discussed. Application of the same technology would directly benefit efforts to provide very stable platforms to meet high pointing accuracy requirements of satellites. The technology would directly benefit efforts to provide very stable platforms to meet high pointing accuracy requirements of satellites. The technology used to develop damped panel designs is discussed briefly, and a cost reliability model used to assess the cost benefit of reduced vibration is described.

86-1012

Application of Damping to Improve Reliability of IUS (Inertial Upper Stage) -Type Satellite Equipment — RELSAT (Reliability for Satellite Equipment in Environmental Vibration Program)

R. Ikegami, C.J. Beck, W.J. Walker

Boeing Aerospace Co., Seattle, WA

(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp TT-1 -TT-15, AD-A152 547) AD-P004 725/8/GAR

KEY WORDS: Spacecraft instrumentation response, Vibration damping, Design techniques

A review of the status of the Boeing Aerospace Company (BAC) RELiability of SATellite Equipment in Environmental Vibration (RELSTAT) Program is presented. The program objectives, approach, goals and schedule are discussed. The work performed to date includes the selection of the BAC Inertial Upper Stage as the baseline system for development in the RELSAT program. A description of work currently being performed is included. This contains typical passive damping design concepts under consideration, and component developmental testing and finite element modeling results.

86-1013

Dynamic Aspects of Army Missile Systems

P.L. Green

U.S. Army Research, Development and Engineering Center, Redstone Arsenal, AL

J. Environ. Sci., 28 (5), pp 40-44 (Sept/Oct 1985) 17 figs

KEY WORDS: Missiles, Environment simulation

An indication of the range of dynamic phenomena involved in Army missile systems can be found in considering the PERSHING II and the VIPER. The PERSHING II, the largest member of our inventory, is a 7,248 kilogram (16,000 pound) missile, while the viper weighs about 1,356 kilograms (3 pounds). Obviously, the structural design philosophy and dynamic environments are at great variance between the two systems. It is the aim of this paper to provide some indication of the range of these problems. A few general observations will be followed by examples taken from recent experiences.

BIOLOGICAL SYSTEMS

HUMAN

86-1014

Application of Sound and Vibration Technology in Air and Space Flight Medicine (Schall- und SchwingungsmeBtechnik für den Einsatz in der Luft-und Raumfahrtmedizin)

N. Schenke

VEB Robotron-MeBelektronik Dresden, German Dem. Rep
Feingeratetechnik, 34 (5), pp 200-202 (1985) 4 figs, 1 table (in German)

KEY WORDS: Human response, Noise tolerance, Vibration tolerance

The determination of effects of noise and vibration on humans in space and in manned flight vehicles is described. A combination of two instruments, the Schumeter and the Vibrometer, are used. The apparatus, mounted in a special container, allows measurements in flight as well as during preparation in ground stations. The Schumer measuring units determine the sound pressure levels relevant to the work place and personnel. The Vibrometer measures the vibration acceleration or velocity. By means of built in filters, the effect of mechanical vibrations on humans or human body parts, such as hand-arm systems, can be determined.

86-1015

Subjective Effects of Combined-Axis Vibration: II. Comparison of X-axis and X-plus-pitch Vibrations

R.W. Shoenberger
Aviation, Space and Environmental Medicine, 56, pp 559-563 (1984) 4 figs, 3 tables, 12 refs

KEY WORDS: Human response, Vibration excitation

Seated subjects matched their perceptions of the intensity of single axis vibrations in the X axis, or combined-axis vibrations made up of X-axis and pitch motions. The intensity of sinusoidal, 5 Hz, Z-axis response vibration is used. Stimulus vibrations were sinusoidal at 3·15, 4,5,6^3 and 7 Hz. For each frequency, both types of vibration were presented at three acceleration levels related to three axis-to-seat distances for the pitch vibrations. Results showed that Z-axis response accelerations were essentially constant across frequency. However, matching responses were significantly higher for X-plus-pitch and X-axis vibrations. These findings are in contrast to those of a previous experiment involving Y-axis and roll vibrations, and are probably due to additional input from the seat back for X and pitch motions. The two experiments do agree on the importance of the distance of the subject from the axis of rotation for angular motions. In both experiments, as stimulus acceleration (axis-to-seat) distance) increased, response acceleration increased substantially at every frequency.

86-1016

Nonlinear Dynamic Analyses of the Fluid-Structure Interaction Problems in Cochlear Mechanics

Ching Long Ko
Ph.D. Thesis, Univ. of Oklahoma, 184 pp (1985) DA8514197

KEY WORDS: Ears, Fluid-structure interaction, Nonlinear theories

Two peculiar phenomena of the response in the cochlea (inner ear) have attracted considerable attention in applied mechanics. One is the phenomenon of the localization of the response with respect to frequency variations and the other is the nonlinearity of the response of the basilar membrane. The localization phenomenon is analyzed by implementing an orthotropic helicoidal shell model. This model takes into account the shell nature of the actual geometry of the basilar membrane. This nature has not been incorporated into previous analyses which are based on either beam or plate theory. The possibility of geometric nonlinearity being the major source is also investigated by an orthotropic circular plate model. Perilymph and endolymph are modeled as inviscid fluids interacting with the basilar membrane. The results of the helicoidal shell analysis indicate that the coiled geometry of the cochlea has little effect on localization. However, the model does not take into account the taper of the basilar membrane along its length. The results of the circular annular plate analysis indicate that the geometric nonlinearity is unlikely to be the major source of the nonlinearity of the cochlea.

86-1017

Hand-Arm Vibration Measurement and Assessment of Occupational Exposure to Vibrating Tools

M. Bovenzi
La Medicina del Lavoro, 75, pp 313-321 (1984) 4 figs, 4 tables, 14 refs (in Italian)

KEY WORDS: Human hand, Vibration response, Pneumatic tools

Hand transmitted vibration generated from 31 pneumatic and electric tools was measured. Requirements for vibration measuring equipment and methods of laboratory analysis of the recording signals are discussed. Some comments are made on the use of integrating vibration meters. The vibration spectra of the tools were measured and r.m.s. overall acceleration, r.m.s. weighted acceleration and r.m.s. acceleration at

the fundamental frequency of the tools (mean values plus or minus S.D., m/s 2) are reported. On the basis of dose-response relationship proposed by ISO/DIS 5349, the risk of onset of vibration-induced white finger in workers using the vibrating tools is examined in this study is evaluated. The need for further research in this field is emphasized and it is suggested that extensive epidemiological and engineering surveys be encouraged in order to assess the risk of occupational exposure to hand-arm vibration in Italy.

KEY WORDS: Vibration isolators, Elastomers, Elastic properties, Damping coefficients, Machine foundations

This work presents the results of the experimental research on the elastic and damping characteristics of isolators made from "Vibramor" -- a new elastic material produced out of rubber waste. The study deals with these new isolators, the methods and devised employed in the research, as well as the resulted elastic and damping characteristics. It is concluded that the new material is endowed with the required properties for the antivibratory isolation of machines and their foundations.

MECHANICAL COMPONENTS

ABSORBERS AND ISOLATORS

86-1018

Hysteretic Dampers in Base Isolation: Random Approach

M.C. Constantinou, I.G. Tadjbakhsh
Drexel Univ., Philadelphia, PA

ASCE J. Struc. Engrg., 111 (4), pp 705-721 (Apr 1985) 9 figs, 3 tables, 26 refs

KEY WORDS: Base isolation, Hysteretic damping

A method of random vibration analysis of base isolated structures with hysteretic dampers is employed. The hysteretic restoring force is modeled by a nonlinear differential equation. The equations of motion for shear type structures are linearized in closed form. Nonstationary response statistics for evolutionary nonwhite excitation are determined by solving the associated Lyapunov matrix differential equation. An optimization study which is based on the stationary response is also presented.

86-1019

Researches on the Elastic and Damping Characteristics of "Vibramor" Vibratory Isolators

V. Butuman
Polytechnic Institute "Traian Vuia", Timişoara

Dynamics of Mach. Foundations, Proc. Symp. Bucharest, Romania, pp 161-170 (Oct 22-24, 1985) 7 tables, 6 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

86-1020

Experimental Research on the Elastic Characteristics of Some Materials Exposed to Cyclic Loading

V. Butuman, S. Holban
Polytechnic Institute "Traian Vuia" Timişoara

Dynamics of Mach. Foundations, Proc. Symp. Bucharest, Romania, pp 171-178 (Oct 22-24, 1985) 4 figs, 4 tables, 9 refs. AVAIL; Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei, 313, 79590 Bucuresti, Romania

KEY WORDS: Vibration isolators, Elastomers, Cyclic loading, Elastic properties

The paper presents the experimental research carried out for determining the elastic characteristics of a new elastic material -- VIBRAMOR-- under the action of repeated cycles of loading-unloading, with variable parameters.

86-1021

A Dynamic Model of the Antivibratory Isolation System of Machine Tools

S.T. Chiriacescu, D.H. Van Campen
Univ. of Braşov, Romania

Dynamics of Mach. Foundations, Proc. Symp. Bucharest, Romania, pp 179-186 (Oct 22-24, 1985) 1 fig, 5 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Vibration isolators, Machine tools, Optimum design

In this paper, a model of the antivibratory isolation system of machine tools is presented. This model can be used for absolute stability analysis of the dynamic machining system for optimum design of antivibratory isolators.

86-1022

Use of Vibration — Isolation System Based on Air Springs for Foundation of Shaking Tables

C.R. Constantinescu, M. Stancu
Building Research Institute - INCERC, Bucharest, Romania

Dynamics of Mach. Foundations, Proc. Symp. Bucharest, Romania, pp 187-194 (Oct 22-24, 1985) 3 figs, 2 tables, 7 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Vibration isolators, Pneumatic springs, Shakers, Seismic tests

The use of a pneumatic technique for vibration isolation offers two important qualities required for the system:small elastic stiffness and great capacity of supporting static loads. The elastic medium used consists of air compressed up to the pressure necessary for supporting the static load. The paper presents how the pneumatic technique can be used for isolating the vibrations produced by shaking tables. Some considerations about the dynamic system, the mathematical model, the theoretical relations for air-spring design, the general design solution, and the main functional parameters of the system are described.

86-1023

Isolators of Weaving Machines

W.-J. Gerasch, H.G. Natke, R. Thiede
Univ. Hannover, West Germany

Dynamics of Mach. Foundations, Proc. Symp. Bucharest, Romania, pp 195-204 (Oct 22-24, 1985) 4 figs, 4 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Vibration isolators, Textile looms

It is important that the planning of weaving mills is carried out in such a way that the vibrations emanating from the mill are not perceptible in residential buildings. In the same way, measures must be taken in existing mills if the vibrations are perceptible in the vicinity. This paper shows the possibilities that exist for reducing the forces emanating from the weaving machines.

86-1024

Practical Application of Vibration Absorbers for Machine Bearer Vibration Protection

B.G. Korenev
Moscow Civil Engineering Institute

Dynamics of Mach. Foundations, Proc. Symp. Bucharest, Romania, pp 205-214 (Oct 22-24, 1985) 2 figs, 14 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Dynamic vibration absorption (equipment), Machine foundations

The task of this paper is to consider possible fields of effective application of dynamic vibration absorbers for machine bearers vibration protection and to describe in general special features of the dynamics problems arising in this connection.

86-1025

The Concept of Dynamic Absorber in the Design of Sturdy Machine Foundations

G. Năstasă
Institute of Engineering and Design for the Chemical Industry, Iaşi, Romania

Dynamics of Mach. Foundations, Proc. Symp. Bucharest, Romania, pp 215-224 (Oct 22-24, 1985) 5 figs, 3 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Dynamic vibration absorption (equipment), Machine foundation

An analysis is made on the possibilities of applying the classical linear dynamic absorber in the design of sturdy machine foundations and the performances of two-mass foundations used to the same purpose.

TIRES AND WHEELS

86-1026

Natural Frequencies and Mode Shapes of an Automotive Tire with Interpretation and Classification Using 3-D Computer Graphics

L.E. Kung, W. Soedel, T.Y. Yang, L.T. Charek

Ray W. Herrick Laboratories
J. Sound Vib., 102 (3), pp 329-346 (Oct 8, 1985) 13 figs, 2 tables, 13 refs

KEY WORDS: Tires, Natural frequencies, Mode shapes, Finite element technique, Graphic methods

Natural frequencies and mode shapes of a radial tire have been obtained by using an efficient, 12 degree of freedom, doubly curved thin shell finite element of revolution with smeared-out properties of laminate composite materials. The finite element formulation includes the geometrical nonlinearities so that the prestressed state of the tire due to inflation is taken into account. Theoretical results are compared with experimental results obtained from modal analysis and good agreement is shown.

BLADES

86-1027
Vibration Analysis of Rotating Turbomachinery Blades by an Improved Finite Difference Method
K.B. Subrahmanyam, K.R.V. Kaza
National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH
Intl. J. Numer. Methods Engrg., 21 (10), pp 1871-1886 (Oct 1985) 1 fig, 5 tables, 32 refs

KEY WORDS: Rotor blades (turbomachinery)

The problem of calculating the natural frequencies and mode shapes of rotating blades is solved by an improved finite difference procedure based on second-order central differences. Lead-lag, flapping and coupled bending-torsional vibration cases of untwisted blades are considered. Results obtained by using the present improved theory have been observed to be close lower bound solutions. The convergence has been found to be rapid in comparison with the classical first-order finite difference method. While the computational space and time required by the present approach is observed to be almost the same as that required by the first-order theory for a given mesh size, accuracies of practical interest can be obtained by using the improved finite difference procedure. A relatively smaller matrix size is obtained, in contrast to the classical finite difference procedure which requires either a larger matrix or an extrapolation procedure for improvement in accuracy.

86-1028
Calculation of Aerodynamic Properties of Turbine Cascades of Profiles at Subsonic Velocities
M. Stastny
Škoda, Concern Enterprise, Plzeň, Czechoslovakia
Strojnicky Casopis, 36 (3), pp 354-364 (1985) 6 figs, 18 refs (in Czech)

KEY WORDS: Turbine blades, Cascades, Aerodynamic characteristics

Described is a calculation of aerodynamic properties of turbine cascades of profiles, based on successive determination of the flow field, boundary layers on the profile, and energy losses due to mixing in the wakes. Enclosed are examples of results obtained for nozzle cascade.

86-1029
Aerodynamic Detuning Analysis of an Unstalled Supersonic Turbofan Cascade
D. Hoyniak, S. Fleeter
NASA Lewis Res. Ctr., Cleveland, OH
Rept. No. E-2546, NASA-TM-87001, 25 pp (Mar 21, 1985) (30th Intern. Gas Turbine Conf. and Exhibit, Houston, TX, Spons. by ASME (Mar 17-21, 1985) N85-26670/8/GAR

KEY WORDS: Cascades, Flutter, Tuning

An approach to passive flutter control is aerodynamic detuning, defined as designed, passage-to-passage differences in the unsteady aerodynamic flow field of a rotor blade row. Thus, aerodynamic detuning directly affects the fundamental driving mechanism for flutter. A model to demonstrate the enhanced supersonic aeroelastic stability associated with aerodynamically detuned cascade operating in a supersonic inlet flow field with a subsonic leading edge locus is analyzed, with the aerodynamic detuning accomplished by means of nonuniform circumferential spacing of adjacent rotor blades.

86-1030
Damping Properties of Steam Turbine Blades
N.F. Rieger
Stress Technology, Inc., Rochester, NY
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp K-1 -K-32) AD-A152 547) AD-P004 694/6/GAR

KEY WORDS: Turbine blades, Damping coefficients, Steam turbines

Material hysteresis, attachment friction and gasdynamic effects are recognized sources of damping in turbomachinery blading. No comparison study of their relative effectiveness appears to have been made, although there are diverse opinions on this topic. This overview paper describes a series of tests which were made to examine the damping properties of several types of steam turbine blades. One objective was to determine the relative contributions from the above damping sources in these blade types. These studies were conducted in a non-rotating damping test rig which used blades mounted in corresponding real disk root attachments.

BEARINGS

86-1031
Optimization of Cascade Blade Mistuning, Part II: Global Optimum and Numerical Optimization
E. Nissim, R.T. Haftka
Virginia Polytechnic Inst. and State Univ., Blacksburg, VA
AIAA J., 23 (9), pp 1402-1410 (Sept 1985) 2 figs, 8 tables, 4 refs

KEY WORDS: Blades, Cascades, Tuning, Optimization, Flutter

The values of the mistuning which yield the most stable eigenvectors are analytically determined. It is also shown that random mistunings, if large enough, may lead to the maximal stability, whereas the alternate mistunings cannot. The problem of obtaining maximum stability for minimal mistuning is formulated, based on numerical optimization techniques. Several local minima are obtained using different starting mistuning vectors. The starting vectors which lead to the global minimum are identified. It is analytically shown that all minima appear in multiplicities which are equal to the number of compressor blades. The effect of mistuning on the flutter speed is studies using both an optimum mistuning vector and an alternate mistuning vector. Effects of mistunings in elastic axis locations are shown to have a negligible effect on the eigenvalues. Finally, it is shown that any general two-dimensional bending-torsion system can be reduced to an equivalent uncoupled torsional system.

86-1032
Coupled Vibration Analysis of Blades with Angular Pretwist of Cubic Distribution
M. Sabuncu
Dokuz Eylul Univ., Bornova-Izmir, Turkey
AIAA J., 23 (9), pp 1424-1430 (Sept 1985) 4 figs, 3 tables, 8 refs

KEY WORDS: Blades, Initial deformation effects, Coupled response, Finite element technique

This paper presents a finite element model for the vibration analysis of pretwisted uniform cross sectional blading. The variation of pretwist along the blade length can be in linear or trigonometric increments. The dynamic stiffness for free vibration of the blade is derived from the strain and kinetic energies using Lagrange's equation. The cubic polynomial approximation of the displacements, in two principal directions, is assumed. This method gives excellent results with the use of only a small number of elements. Good agreement is found with the experimental and theoretical results of other investigators for straight and linearly pretwisted blades. The comparison of theoretical results between the linearly and nonlinearly pretwisted beams shows large deviations when the pretwist angle increases.

GEARS

86-1033
Fatigue Life Analysis of a Turboprop Reduction Gearbox
D.G. Lewicki, J.D. Black, M. Savage, J.J. Coy
NASA Lewis Res. Ctr., Cleveland, OH
Rept. No. E-2559, NASA-TM-87014, 25 pp (1985)
N85-27228/4/GAR

KEY WORDS: Gearboxes, Fatigue life

A fatigue life analysis of the Allison T56/501 turboprop reduction gearbox was developed. The life and reliability of the gearbox was based on the lives and reliabilities of the main power train bearings and gears. The bearing and gear lives were determined using the Lundberg-Palmgren theory and a mission profile. The five planet bearing set had the shortest calculated life among the various gearbox components, which agreed with field experience where the planet bearing had the greatest incidences of failure. The analytical predictions of relative lives among the various berarings were in reasonable agreement with field experience. The predicated gearbox life was in excellent agreement with field data when the material life adjustment factors alone were used.

FASTENERS

86-1034

Effect of Stitching on the Strength of Bonded Composite Single Lap Joints

J.W. Sawyer

NASA Langley Research Ctr., Hampton, VA

AIAA J., 23 (11), pp 1744-1748 (Nov 1985) 11 figs, 2 tables, 5 refs

KEY WORDS: Joints, Fatigue life

An experimental investigation has been conducted to determine the effect of stitching on the static and fatigue failure load of bonded composite single lap joints. The variables considered in the static tests included adherend thickness, overlap length, stitch spacing, and number of rows of stitches. A limited fatigue program was conducted for one configuration to compare the fatigue life of stitched and unstitched joints. Up to 38% improvement in static failure load and an order of magnitude increase in fatigue life compared with unstiffened results are obtained by a single row of stitches near the end of the overlap. Additional rows of stitching or different stitch spacing has little effect on static joint failure load. Thicker adherends and larger overlap length result in larger improvements in static failure load with stitching. Further research is needed to refine the stitching process in order to obtain the maximum improvements in joint failure load.

86-1035

Complex Modulus Behavior of a Viscoelastic Adhesive Measured at Harmonic Strain Amplitudes of 10-10

T.J. Lagnese, D.I.G. Jones

Wright-Patterson AFB, OH

(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp E-1 -E-17, AD-A152 547) AD-P004 690/4/GAR

KEY WORDS: Adhesives, Viscoelastic properties, Complex modulus, Dynamic stiffness

The complex modulus behavior of a viscoelastic material, measured by a dynamic stiffness method, was determined at several low excitation levels, and several temperatures, to illustrate the effect of strain amplitude. The material was found to be linear to strain levels as low as 10 to the minus tenth power m/m.

86-1036

Fatigue Strength of Weathered and Deteriorated Riveted Members

J.M.M. Out, J.W. Fisher, B.T. Yen

Lehigh Univ., Bethlehem, PA

Rept. No. DOT/OST/P34-85/016, 108 pp (Oct 1984) PB85-207900/GAR

KEY WORDS: Riveted joints, Fatigue life

This report describes a study that has been performed on the fatigue and fracture resistance of corroded and deteriorated riveted members. A detailed literature study is included which examines available test data on the fatigue behavior of riveted members. The most important variables on the fatigue strength of such members have been determined as well as the way and to what extent they influence the fatigue life. The previous test programs provided no information on the applicability of the Category D fatigue limit and little on riveted connections other than simple splices. Fatigue tests were carried out on six 80 year old steel bridge stringers with a riveted built-up cross section. The stringers were significantly corroded along the compression flange, and locally at the tension flange. They were subjected to stress ranges that were between the fatigue limits.

SEALS

86-1037

Non-Linear Dynamic Analysis of Noncontacting Coned-Face Mechanical Seals

I. Green, I. Etsion

Technion-Israel Inst. of Tech., Haifa, Israel

Rept. No EEC-154, 52 pp (Aug 1984) DE85900588/GAR

KEY WORDS: Seals, Rotors, Critical speeds

The complete nonlinear equations of motion of a flexibly mounted stator in a noncontacting cone-face mechanical seal are solved numerically. The solution utilizes a transient dynamic analysis and takes into account rotor axial runout and assembly tolerances in the form of initial stator misalignment. Cavitation of the fluid film is also accounted for. A parametric investigation is performed and the effect of various design parameters and operation conditions on the seal dynamics is presented and discussed. A critical shaft speed is found above which the seal becomes dynamically unstable. A critical rotor runout is found which, if exceeded, will cause

seal failure due to local face rubbing contact. A comparison is made between the numerical results and those of a simpler analytical solution. It is found that the analytical solution is valid for most practical applications of mechanical seals.

STRUCTURAL COMPONENTS

STRINGS AND ROPES

86-1038
Dynamic Mechanical Properties of Graphite/Aluminum Wires at Audio-Frequencies
G.F. Lee, C.W. Anderson
Naval Surface Weapons Ctr., Silver Spring, MD
(Vibr. Damping Workshop Proceedings, Long Beach, CA, Feb 27-29, 1984, pp T-1 - T-16, AD-A152 547) AD-P004 703/5/GAR

KEY WORDS: Wires, Aluminum, Graphite, Audio frequencies

Twenty graphite/aluminum wires used in this study have been shown by x-ray to have voids due to poor impregnation of aluminum in the graphite fibers. The dynamic mechanical properties of these wires were also determined. It was found that the dynamic mechanical properties correlated with the x-ray results. The following properties were determined at room temperature: torsional properties - logarithmic decrement and shear modulus at approximately 0.5 Hz and flexural properties - logarithmic decrement and bending stiffness over a frequency range of 10 to 500 Hz.

CABLES

86-1039
Large-Amplitude Vibrations of Parabolic Cables
S.I. Al-Noury, S.A. Ali
King Abdulaziz University, Jeddah, Saudi Arabia
J. Sound Vib., 101 (4), pp 451-462 (Aug 22, 1985) 5 figs, 15 refs

KEY WORDS: Cables

The nonlinear equations of motion for the coupled transverse-vertical vibrations of parabolic cables are presented. Approximate solutions are developed by using the method of multiple scales. Solutions and numerical results are obtained and discussed for special cases.

BEAMS

86-1040
Distributed Piezoelectric-Polymer Active Vibration Control of a Cantilever Beam
T. Bailey, J.E. Hubbard
Massachusetts Inst. of Tech., Cambridge, MA
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp XX-1 - XX-23, AD-A152 547) AD-P004 728/2/GAR

KEY WORDS: Cantilever beams, Active damping, Continuous parameter method

An active vibration damper for a cantilever beam was designed using a distributed-parameter actuator and distributed-parameter control theory. The distributed-parameter actuator was a piezoelectric polymer, poly(vinylidene fluoride). Lyapunov's second method for distributed-parameter systems was used to design a control algorithm for the damper. If the angular velocity of the tip of the beam is known, all modes of the bean can be controlled simultaneously. Preliminary testing of the damper was performed on the first mode of the cantilever beam. A linear, constant-gain controller and a nonlinear constant-amplitude controller were compared.

86-1041
On the Dynamic Stability of a Pre-Twisted Beam Subject to a Pulsating Axial Load
M. Gürgöze
Technical Univ. of Istanbul, Istanbul, Turkey
J. Sound Vib., 102 (3), pp 415-422 (Oct 8, 1985) 4 figs, 9 refs

KEY WORDS: Beams, Initial deformation effects, Axial force

This paper is concerned with the investigation of the stability behavior of pre-twisted beam, subject to a pulsating axial force. The stability of the solutions of this system is investigated by the method of Mettler. Then the equations of the boundaries of the instability regions are given in

a parameter-plane. Finally, the results obtained are applied for various types of boundary conditions.

86-1042
Nonlinear Equations for Dynamics of Pretwisted BEAMS Undergoing Small Strains and Large Rotations
D.H. Hodges
NASA Ames Res. Ctr., Moffett Field, CA
Rept. No. A-9833, NASA-TP-2470, 35 pp (May 1985) N85-27258/1/GAR

KEY WORDS: Beams, Initial deformation effects, Nonlinear theories

Nonlinear beam kinematics are developed and applied to the dynamic analysis of a pretwisted, rotating beam element. The common practice of assuming moderate rotations caused by structural deformation in geometric nonlinear analyses of rotating beams was abandoned in the present analysis. Numerical results obtained for nonlinear static problems show remarkable agreement with experiment.

86-1043
Dynamic Analysis of Beam-Column Embedded in an Elastic Medium
C.G. Date
Ph.D. Thesis, Arizona State Univ., 258 pp (1985) DA8514342

KEY WORDS: Beam-columns, Elastic medium, Soil-structure interaction, Harmonic excitation

A general method is presented for the analysis of systems of beam-columns embedded partially or fully in an elastic medium. They are subjected to time dependent loads of harmonic variations. The analysis is restricted to systems of straight bars of constant cross section with two orthogonal axes of symmetry, subjected to time independent axial load. The analysis also assumes linear elasticity, small deformations, linear vibrations without damping and a linear elastic medium defined as Winkler's foundation. A procedure is presented the generates the finite element matrices from the truncated stiffness series. It selects the finite element mesh within the predetermined range of accuracy. The application is illustrated by four numerical examples. Two computer programs, plane frame analyzer and space frame analyzer, are also included.

86-1044
Beam on Generalized Two-Parameter Foundation
T. Nogami, M.W. O'Neill
Univ. of Houston, Houston, TX
ASCE J. Engrg. Mech., 111 (5), pp 664-679 (May 1985) 10 figs, 6 refs

KEY WORDS: Beams, Soil-structure interaction

A method for analysis of beams bearing on a ground surface is presented. The method is based on treating the soil medium as a generalized two-parameter model. The inputs required for the model are dimensions and material properties only. This contrasts to other two-parameter models in which the parameters are based upon assumed soil displacement distributions that may be difficult to predict before the analysis. Analyses whos the new two-parameter model can yield responses of loaded beams reasonably close to those computed by using continuum solutions or a finite element method.

86-1045
Further Flexural Vibration Curves for Axially Loaded Beams with Linear or Parabolic Taper
J.R. Banerjee, F.W. Williams
Univ. of Wales Institute of Science and Technology, Cardiff, Wales
J. Sound Vib., 102 (3), pp 315-327 (Oct 8, 1985) 10 figs, 1 table, 4 refs

KEY WORDS: Beams, Parabolic bodies, Flexural vibration, Variable cross section

Curves are presented which enable the first five natural frequencies to be found for axially loaded tapered members with an important family of cross sections. These cross sections complement those of an earlier paper, such that the curves in the two papers cover all of the most common types of tapered member. The curves illustrate how natural frequencies and buckling loads are altered by changing the amount and type of a member's taper while keeping its mass constant. Finally, it is shown that, for the ranges covered by the curves, frequencies which separate the first five natural frequencies can be found a priori. The theory used to obtain the curves was simply to divide the tapered member

into sufficient uniform mem[illegible] ensure convergence to the tapered re[illegible] o better than plotting accuracy.

86-1046
A Finite Element Method for Non-Linear Forced Vibrations of Beams
C. Mei, K. Decha-Umphai
Old Dominion Univ., Norfolk, VA
J. Sound Vib., 102 (3), pp 369-380 (Oct 8, 1985) 6 figs, 4 tables, 13 refs

KEY WORDS: Beams, Nonlinear response, Harmonic excitation, Finite element technique

Geometric nonlinearities for large amplitude free and forced vibrations of beam are investigated. Longitudinal displacement and inertia are included in the formulation. The finite element method is used. The harmonic force matrix is introduced and derived. Various out-of-plane and inplane boundary conditions are considered. Results showing the dependence of the amplitude on the frequency ratio and on the strain are presented for different boundary conditions and loads. It is concluded that the effects of longitudinal deformation and inertia are to reduce the nonlinearity.

86-1047
Counterintuitive Behavior in a Problem of Elastic-Plastic Beam Dynamics
P.S. Symonds, T.X. Yu
Brown Univ., Providence, RI
J. Appl. Mech., Trans. ASME, 52 (3), pp 517-522 (Sept 1985) 7 figs, 11 refs

KEY WORDS: Beams, Pulse excitation, Elastic-plastic properties

In a particular example of short pulse loading on a pin-ended beam, the permanent deflection is predicted by a numerical solution to be in the direction opposite that of the load. Analysis of a Shanley-type model shows that this surprising behavior may occur as a consequence of plastic irreversibility, combined with geometric nonlinearity, when the peak deflection produced by the pulse lies in a certain range of small magnitudes. Results from a number of well-known structural dynamics codes are shown. These exhibit a wide spread in the predicted final deflections, indicating strong sensitivities of both physical and computational nature.

86-1048
Dynamic Fracture of an Idealized Fiber-Reinforced Cantilever
L.F. Mannion
St. John's Univ., Jamaica, NY
J. Appl Mech., Trans. ASME, 52 (3), pp 580-584 (Sept 1985) 2 figs, 9 refs

KEY WORDS: Cantilever beams, Fiber composites, Fracture properties

The dynamic fracture of a double cantilever beam of fiber-reinforced material is discussed. The material is modeled by assuming that the fibers are inextensible and continuously distributed. The examples considered reduce to the solution of the wave equation on a time-dependent interval. The method of characteristics is used. Two fracture criteria are used to calculate the crack speed. One of these criteria is the energy release rate commonly used in elastic fracture mechanics. In the present model some fibers can carry a finite force; the second criterion is based on the force in the fiber through the crack tip. Three simple examples are given to illustrate the model.

86-1049
Extensions of the Ritz-Galerkin Method for the Forced, Damped Vibrations of Structural Elements
A.W. Leissa, T.H. Young
Ohio State Univ., Columbus, OH
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp EE-1 -EE-22, AD-A152 547) AD-P004 713/4/GAR

KEY WORDS: Structural members, Cantilever beams, Viscous damping, Hysteretic damping, Ritz-Galerkin method

The classical method for analyzing the forced vibrations of structural elements such as beams, plates and shells is to express the displacements as superpositions of the responses of the free vibration modes. This is only possible for those relatively few problems where exact eigenfunction solutions exist, and often only with considerable difficulty. Ritz-Galerkin methods are widely used to obtain approximate solutions for free undamped, vibration problems. The present paper demonstrates how these same methods may be used straightforwardly to analyze forced vibrations with damping. This is done directly without requiring the free vibration eigenfunctions. Two types of damping--viscous and material (hysteretic) are considered. Both dis-

tributed and concentrated exciting forces are treated. Numerical results are obtained for cantilevered beams and rectangular plates. Studies showing the rates of convergence of the solutions are made. In the case of the cantilever beam, approximate solutions from the present methods are compared with the exact solutions.

COLUMNS

86-1050
Dynamic Instability Analyses of Axially Impacted Columns
Kunitomo Sugiura, Eiji Mizuno, Yuhshi Fukumoto
State Univ. of New York at Buffalo, Buffalo, NY
ASCE J. Engrg. Mech., 111 (7), pp 893-908 (July 1985) 12 figs, 2 tables, 26 refs

KEY WORDS: Columns, Axial excitation, Dynamic stability

The dynamic response and critical state of an inelastic simply supported column under an axial impact are studied. This problem is analyzed by solving the dynamic Bernoulli-Euler equation with an axial inertia effect within the framework of finite difference approach. The influence of strain-rate effects on the dynamic response is first examined by using an elastic-viscoplastic theory. Then the critical values of an initial velocity and a mass of striking body for losing stability are evaluated within the context of the numerical results from different initial and boundary conditions. It is found that strain-rate effects are important in the range of post-dynamic instability. In addition the mode of the lateral displacement after an impact depends on the initial velocity of the striking body and also on the relationship between the natural period of the first-order lateral mode and that of the first-order axial mode. Present study can give a basic guide to evaluate the dynamic instability of axially impacted columns from a viewpoint of the energy loss of the striking body.

86-1051
Influence of Construction Parameters to Forced Oscillations of Turbo-Generator Columns - Part 1 (Einfluß von Konstruktionsparametern auf die erzwungenen Schwingungen von Turbogenerator-ständern — Teil 1)
D. Albrecht, W. Krause, W.E. Kruger
Ingenieurhochschule Zittau, Sektion Kraftwerksanlagen und Energieumwandlung Maschinenbau
Maschinenbautechnik, 34 (4), pp 166-169 (1985) 9 figs, 8 refs (in German)

KEY WORDS: Turbogenerators, Columns, Oscillation

Field of application of an existing double-disk model of a generator column for calculation of natural frequency is enlarged to forced oscillation. On variation of essential system parameters amplitudes of the sheet-pack housing at the time are determined. Results of calculation are graphically represented.

MEMBRANES, FILMS, AND WEBS

86-1052
Transverse Vibrations of Composite Membranes of Arbitrary Boundary Shape
P.A.A. Laura, L. Ercoli, R.O. Grossi, K. Nagaya
Institute of Applied Mechanics, Puerto Belgrano Naval Base, Argentina
J. Sound Vib., 101 (3), pp 299-306 (Aug 8, 1985) 2 figs, 4 tables, 7 refs

KEY WORDS: Membranes, Composite structures, Flexural vibrations, Conformal mapping

This paper deals with an approximate method based on the technique of conformal mapping and a variational formulation which allows for a straightforward solution of the title problem for a certain type of composite membranes. Numerical results are presented for membranes of regular polygonal shape. The fundamental eigenvalues are also verified by the Fourier expansion-collocation method and by a finite element algorithm.

PANELS

86-1053
Effect of Low-Velocity or Ballistic Impact Damage on the Strength of Thin Composite and Aluminum Shear Panels
G.L. Farley
NASA Langley Res. Ctr., Hampton, VA
Rept. No. L-15942, NASA-TP-2441, 40 pp (May 1985) N85-26924/9/GAR

KEY WORDS: Panels, Aluminum, Composite materials, Impact tests

Impact tests were conducted on shear panels fabricated from 6061-T6 aluminum and from woven fabric pre-preg of DuPont Kevlara fiber/epoxy resin and graphite fiber/epoxy resin. The shear panels consisted of three different composite laminates and one aluminum material configuration. Three panel aspect ratios were evaluated for each material configuration. The results of these tests indicate that ballistic threshold load (the lowest load which will result in immediate failure upon penetration by the projectile) varied between 0.44 and 0.61 of the average failure load of undamaged panels. Good agreement was obtained between the experimental failure strengths and the predicted strength with the point stress failure criterion.

PLATES

86-1054
A Study of Dynamic Instability of Plates by an Extended Incremental Harmonic Balance Method
C. Pierre, E.H. Dowell
Duke Univ., Durham, NC
J. Appl. Mech., Trans. ASME, 52 (3), pp 693-697, (Sept 1985) 5 figs, 10 refs

KEY WORDS: Plates, Harmonic balance method, Parametric vibrations

The dynamic instability of plates is investigated with geometric nonlinearities being included in the model, which allows one to determine the amplitude of the parametric vibrations. A modal analysis allowing one spatial mode is performed on the nonlinear equations of motion and the resulting nonlinear Mathieu equation is solved by the incremental harmonic balance method. It takes several temporal harmonics into account. When viscous damping is included, a new algorithm is proposed to solve the equation system obtained by the incremental method. For this purpose, a new characterization of the parametric vibration by its total amplitude -- or Euclidian norm -- is introduced. This algorithm is particularly simple and convenient for computer implementation. The instability regions are obtained with a high degree of accuracy.

86-1055
Numerical Investigation of Vibrational Energy Transmission in Coupled Structures: Case of L,T and + Shape Coupled Plates (Etude numérique de la transmission d'énergie vibratoire entre structures assemblées: cas d'assemblages en L,T et +)
C. Boisson, J.L. Guyader, C. Lesueur
Institut National des Sciences Appliquées de Lyon, Villeurbanne Cedex, France
Acustica, 58 (4), pp 223-233 (Sept 1985) 25 figs, 1 table, 6 refs (in French)

KEY WORDS: Plates, Energy transmission, Damping effects, Geometric effects

In this paper a survey of numerical results on vibrational energy transmission in L, T or cross shape coupled-plates is provided. The influences of damping, thickness, area of the plates, and with special attention, that of the type of excitation (mechanical or acoustical) are shown. Means of energy reduction using nonsymmetrical plates, stiffeners at junctions and damping are then presented.

86-1056
Large-Amplitude Oscillations of Unsymmetrically Laminated Anisotropic Rectangular Plates Including Shear, Rotatory Inertia, and Transverse Normal Stress
K.S. Sivakumaran, C.Y. Chia
McMaster Univ., Hamilton, Ontario, Canada
J. Appl. Mech., Trans. ASME, 52 (3), pp 536-542 (Sept 1985) 10 figs, 21 refs

KEY WORDS: Rectangular plates, Layered materials, Rotatory inertia effects, Transverse shear deformation effects

This paper is concerned with nonlinear free vibrations of generally laminated anisotropic elastic plates. Based on Reissner's variational principle a nonlinear plate theory is developed. The effects of transverse shear, rotatory inertia, transverse normal stress, and transverse normal contraction or extension are included in this theory. Using the Galerkin procedure and principle of harmonic balance, approximate solutions to governing equations of unsymmetrically laminated rectangular plates including transverse shear, rotatory inertia, and transverse normal stress are formulated for various boundary conditions. Numerical results for the ratio of nonlinear frequency to linear frequency of unsymmetric angle-ply and cross-ply laminates are presented. Graphical results are given for various values of elastic properties, fiber orientation angle, number of layers, and aspect ratio and for different boundary conditions. Present results are also compared with available data.

86-1057
Transverse Vibrations of Rectangular Plates on Inhomogeneous Foundations, Part I: Rayleigh-Ritz Method
P.A.A. Laura, R.H. Gutierrez

Institute of Applied Mechanics, Puerto Belgrano Naval Base, Argentina
J. Sound Vib., 101 (3), pp 307-315 (Aug 8, 1985) 2 figs, 6 tables, 4 refs

KEY WORDS: Rectangular plates, Flexural vibrations, Winkler foundations, Raleigh-Ritz method

The title problem is solved for the case of Winkler-type inhomogeneous foundation and when the plate edges are elastically restrained against rotation. Fundamental frequency coefficients are determined for several combinations of length to width ratios and flexibility coefficients. The solution given in Part I is based on the Rayleigh-Ritz method and polynomial co-ordinate functions while the problem is solved in Part II by means of the modal constraint method.

86-1058
Transverse Vibrations of Rectangular Plates on Inhomogeneous Foundations, Part II: Modal Constraint Method
J.A.G. Horenberg, J.G.M. Kerstens
Shell Research B.V., Rijswijk ZH, The Netherlands
J. Sound Vib., 101 (3), pp 317-324 (Aug 8, 1985) 4 figs, 4 tables, 4 refs

KEY WORDS: Rectangular plates, Flexural vibrations, Elastic foundations, Modal constraint method

A method is described for establishing the lowest natural frequencies of simply supported and clamped plates on inhomogeneous elastic foundations. The method is based upon the modal constraint technique. The merits of this method lie in the fact that the eigenvalues and eigenfunctions of a simply supported plate and scalar springs are used to calculate the eigenvalues of the modified structures. These modifications consist of coupling these structures and/or adding rotational constraints. A number of configurations of inhomogeneous elastic foundations have been considered. Excellent agreement is shown to exist between the eigenvalues determined in the present paper and those calculated using the Rayleigh-Ritz method by Laura and Gutierrez.

86-1059
Thermal Effect on the Transverse Vibration of High-Speed Rotating Anisotropic Disk
N.C. Ghosh
Jadavpur Univ., Calcutta, India
J. Appl. Mech., Trans. ASME, 52 (3), pp 543-548 (Sept 1985) 19 refs

KEY WORDS: Disks, Flexural vibrations, Temperature effects

An attempt has been made to consider the thermal effect on the transverse vibration of a high-speed rotating disk in a steady-state heat conduction. The material of the disk, in this case, is assumed to be thermomechanically anisotropic. The present attempt is made with an objective to provide some theoretical studies on the problem that may serve as a base from which more detailed investigations with regard to the usage of composite material may be attempted to gain new and needed design information regarding turbine disks and thereby to reduce the chances of turbine failure. In this connection a new critical speed of disk rotation has been obtained and consequently this critical speed is found to depend on central temperature, thermomechanical anisotropy, and so forth.

86-1060
Vibration and Stability of Circular Plates Under Partially Distributed or Concentrated Inplane Loads
Y. Narita
Hokkaido Institute of Technology, Sapporo, Japan
J. Appl. Mech., Trans. ASME, 52 (3), pp 549-552 (Sept 1985) 5 figs, 2 tables, 16 refs

KEY WORDS: Circular plates, Flexural vibrations, Natural frequencies, Dynamic buckling

A method is presented for analyzing the free transverse vibration and elastic stability of circular plates under nonuniform distribution of the inplane stresses. A general solution procedure is developed, and a frequency equation is derived for the case when a pair of loads are locally distributed in the plane along the edge. Numerical results are presented for natural frequencies and bucking loads of the plates, and the effect of the partial inplane loading is discussed. A limiting case for a concentrated inplane load is also considered.

86-1061
Thermal Gradient Effects Upon the Vibrations of Certain Composite Circular Plates, Part I: Plane Orthotropic
D.G. Gorman

Univ. of London, London, England
J. Sound Vib., 101 (3), pp 325-336 (Aug 8, 1985) 2 figs, 3 tables, 31 refs

KEY WORDS: Circular plates, Composite structures, Temperature effects, Flexural vibrations

The effect of a radial parabolic temperature distribution upon the natural frequencies of small free transverse vibration (axi- and non-axisymmetric) of polar orthotropic circular plates is considered. Although the problem is solved primarily by means of the annular finite element method, close examination of the exact form of the thermal stress distribution, and utilization of the Lamb and Southwell approximation, enables one to present the results in a very efficient form.

86-1062
Thermal Gradient Effects Upon the Vibration of Certain Composite Circular Plates, Part II: Plane Orthotropic with Temperature Dependent Properties
D.G. Gorman
Univ. of London, London, England
J. Sound Vib., 101 (3), pp 337-345 (Aug 8, 1985) 5 figs, 5 refs

KEY WORDS: Circular plates, Composite structures, Temperature effects, Flexural vibrations

This paper extends the work contained in Part I to include the extra complicating effect of temperature dependent Young's moduli upon the transverse vibration of polar orthotropic circular plates. Two aspects are considered, namely the effect upon the flexural aspect of the plate and the effect upon the geometric stiffness resulting from the more complicated form of the radial stress distribution.

86-1063
Investigation into the Comparisons of the Underwater Shock Effects on a Stiffened Flat Plate to the Predictive Nature of a Computer Model
J.R. Langan
Naval Postgraduate School, Monterey, CA
Master's Thesis, 75 pp (Mar 1985) AD-A155 612/5/GAR

KEY WORDS: Siffened plates, Underwater shock waves, Underwater explosions, Computer programs

An experiment was performed to study the effects of an underwater explosion on a submerged test panel. An important element of this thesis was to validate a finite element/finite central difference computer code developed to forecast shell responses. Emphasis was placed upon attaining stiffener tripping and collecting invaluable dynamic flat plate tripping data.

86-1064
The Effect of Point Constraints on Transverse Vibration of Cantilever Plates
Y. Narita
Hokkaido Institute of Technology, Sapporo, Japan
J. Sound Vib., 102 (3), pp 305-313 (Oct 8, 1985) 4 figs, 4 tables, 11 refs

KEY WORDS: Cantilever plates, Flexural vibration, Natural frequencies, Mode shapes, Lagrange equations

This paper deals with the free transverse vibration of rectangular cantilever plates subjected to point constraints against deflection. Particular emphasis is given to the quantitative evaluation of effects of the constraints on the vibration characteristics. The natural frequencies and mode shapes of the plates are determined by the Lagrange multiplier method, an extension of the classical Ritz method. In the numerical examples it is found that a significant increase in frequencies occurs when the constraints are added on certain parts of cantilever plates.

SHELLS

86-1065
Influence of Foundation Mass on the Nonlinear Damped Response of Orthotropic Shallow Spherical Shells
Y. Nath, R.K. Jain
Indian Institute of Technology, New Delhi, India
Intl. J. Mech. Sci., 27 (7/8), pp 471-479 (1985) 9 figs, 1 table, 8 refs

KEY WORDS: Spherical shells, Winkler foundations, Pasternak foundations, Damped structures, Periodic excitation

The effect of the mass of the foundations on the large-amplitude response of clamped and simply-supported orthotropic shallow spherical shells continuously supported by Winkler and Pasternak

elastic foundations, subjected to uniform step pressure and sinusoidal pulse loadings has been investigated, with and without damping. Nonlinear governing partial differential equations of motion are derived and solved in space and time-domains using Chebyshev polynomials and an implicit Houbolt time-marching scheme, respectively. Results show a significant influence of the foundation inertia on the amplitude and time-period of the response of orthotropic shallow spherical shells.

86-1066
Axisymmetric Static and Dynamic Buckling of Orthotropic Shallow Conical Caps
P.C. Dumir, K.N. Khatri
Indian Inst. of Technology, New Delhi, India
AIAA J., 23 (11), pp 1762-1767 (Nov 1985) 6 figs, 2 tables, 13 refs

KEY WORDS: Spherical shells, Dynamic buckling

This study deals with the axisymmetric static and dynamic buckling of elastic polar orthotropic thin shallow conical caps subjected to uniformly distributed loads. Static and step function conservative loadings on conical caps with clamped immovable, simply supported immovable, and simply supported movable edges have been considered. The governing equations are formulated in terms of normal displacement w and stress function Psi. Orthogonal point collocation method is used for spatial discretization and Newmark-B scheme is used for time marching. The present results for the isotropic clamped immovable conical caps are in good agreement with the available results. The influence of orthotropic parameter B and the edge conditions on the static and dynamic buckling loads has been investigated. Dynamic buckling loads obtained from static analysis have been found to agree well with the dynamic buckling loads based on transient response.

86-1067
Seismic Analysis of Axisymmetric Shells
R.J. Jospin, E.M. Toledo, R.A. Feijoo
Laboratorio de Computacao Cientifica, Rio de Janeiro, Brazil
Rept. No. LCC-12/84, 17 pp (1984) DE85781136/GAR

KEY WORDS: Shells, Seismic analysis, Finite element technique

Axisymmetric shells subjected to multiple support excitation are studied. The shells are spatially discretized by the finite element method and in order to obtain estimates for the maximum values of displacements and stresses the response spectrum technique is used. Finally, some numerical results are presented and discussed in the case of a shall of revolution with vertical symmetry axis, subjected to seismic ground motions in the horizontal, vertical and rocking directions.

86-1068
A New Displacement Form for the Nonlinear Equations of Motion of Shells of Revolution
J.G. Simmonds
Univ. of Virginia, Charlottesville, VA
J. Appl. Mech., Trans. ASME, 52 (3), pp 507-529 (Sept 1985) 10 refs

KEY WORDS: Shells of revolution, Axisymmetric vibrations

In the theory of shells of revolution undergoing torsionless, axisymmetric motion, an extensional and a bending hoop strain are introduced that are linear in the displacements, regardless of the magnitudes of the strains and the meridional rotation. The resulting equations of motion and boundary conditions are derived and some common conservative surface loads are listed along with their potentials. The governing equations appear to be the simplest possible in terms of displacements.

PIPES AND TUBES

86-1069
Vibration of Tube Bundles Subjected to Two-Phase Cross-Flow
M.J. Pettigrew, J.H. Tromp, J. Mastorakos
Atomic Energy of Canada Limited, Chalk River, Ontario, Canada
J. Pressure Vessel Tech., Trans. ASME, 107 (4), pp 335-343 (Nov 1985) 14 figs, 1 table, 13 refs

KEY WORDS: Tube arrays, Fluid-induced excitation, Damping coefficients, Fluid elastic instability, Turbulence

Two-phase cross flow exists in many shell-and-tube heat exchangers such as condensers, reboilers and nuclear steam generators. A com-

prehensive program to study tube bundle vibrations subjected to two-phase cross flow is described. This paper presents the results of experiments on a normal-triangular and a normal-square tube bundle. The bundles were subjected to air-water mixtures to simulate realistic vapor qualities and mass fluxes. Vibration excitation mechanisms were deduced from vibration response measurements. Results on damping, hydrodynamic mass, fluid-elastic instability and random turbulence excitation in two-phase cross flow are presented.

86-1070

Bond Graph Models for Fluid Networks Using Modal Approximation

D.L. Margolis, W.C. Yang
University of California, Davis, CA

J. Dynam. Syst., Meas. Control, Trans. ASME, 107 (3), pp 169-175 (Sept 1985) 14 figs, 30 refs

KEY WORDS: Modal analysis, Bond graph technique, Transmission lines, Pipelines

Modal bond graph representations of the dissipative model of rigid, cylindrical fluid transmission lines with laminar flow are developed. Modal approximation techniques are used for both hydraulic and pneumatic lines. The modeling and simulation procedures for fluid networks coupled with nonlinear and dynamic systems are greatly facilitated using bond graphs. The physical interpretation of the model is preserved in this approach. Simulation results for hydraulic single lines are compared with results derived by the quasi-method of characteristics. The simulation results for fluid networks for various line and termination configurations are illustrated.

86-1071

The Open and Blocked Distributed Air Transmission Lines by the Fast Fourier Transform Method

S.H.L. Tsang, M.W. Benson, R.H. Granberg
Lakehead Univ., Thunder Bay, Ontario, Canada

J. Dynam. Syst., Meas. Control, Trans. ASME, 107 (3), pp 213-219 (Sept 1985) 9 figs, 15 refs

KEY WORDS: Pneumatic lines, Transmission lines, Fast Fourier transform, Computerized simulation

This paper deals with the digital computer simulation of a distributed air transmission line subjected to an impulse, step, or arbitrary excitation. The rationale is based on the inverse Fourier transform principle. The predicted dynamics of a blocked and an open line subjected to arbitrary periodic excitation are compared with experimental measurements. The paper also presents some mathematical proofs.

86-1072

Vibration of Piping Systems Containing a Moving Medium

C.W.S. To, V. Kaladi
The Univ. of Calgary, Calgary, Alberta, Canada

J. Pressure Vessel Tech., Trans. ASME, 107 (4), pp 344-349 (Nov 1985) 5 figs, 1 table, 20 refs

KEY WORDS: Pipelines, Fluid-filled containers, Fluid-induced excitation, Transfer matrix method

The subject of vibration of piping components containing a moving medium has been studied extensively in the past three decades. Special attention has been paid on the instability of uniform and tapered tubes with various boundary conditions. On the other hand, very limited information is available for complex piping systems carrying a moving medium. This paper proposes a transfer matrix method for the vibration analysis of complicated piping networks. Bends, piping components of various diameters, and lumped masses such as valves with a moving medium are considered. Closed-form transfer matrix for various piping elements incorporating the Coriolis effects are presented and discussion is made. The proposed approach is much more economical to use than the versatile finite element method. Moreover, it can be easily implemented in a microcomputer.

86-1073

Transient Hydroelastic Vibration of Piping with Local Nonlinearities

R.P. Keskinen
Finnish Centre for Radiation and Nuclear Safety, Helsinki, Finland

J. Pressure Vessel Tech., Trans. ASME, 107 (4), pp 350-355 (Nov 1985) 7 figs, 1 table, 15 refs

KEY WORDS: Pipelines, Nonlinear systems, Fluid-induced excitation, Modal superposition method

A mode superposition algorithm is presented to solve fluid and structural dynamics problems in piping systems. A local cross sectional material

nonlinearity, such as cavitation of fluid or circumferential cracking of the pipe material can be considered. Two families of eigenmodes are used to decompose the total response into so-called compatibility-controlling and resistance-controlling responses which satisfy the governing partial differential equations. The responses are simultaneously solved in time by means of convolution integral techniques.

86-1074

An Assessment of Frequency-Dependent Damping Using the Nuclear Piping System Damping Data Base

A.G. Ware

EG&G Idaho, Inc., Idaho Falls, ID

J. Pressure Vessel Tech., Trans. ASME, 107 (4), pp 361-365 (Nov 1985) 16 figs, 16 refs

KEY WORDS: Pipelines, Nuclear reactor components, Damping coefficients, Seismic response

The existing nuclear piping damping data base is examined to assess the relation between frequency and damping in the seismic range (0 to 33 Hz). A conclusion is reached that the published data supports such a correlation for individual systems, and that this relation offers suitable advantages for use in establishing allowable damping values for seismic analyses. The data base for higher frequency systems subjected to flow-induced loads is presently very meager, and thus a corresponding assessment cannot be made.

86-1075

Damping in LMFBR Pipe Systems

M.J. Anderson, D.A. Barta, M.R. Lindquist, E.J. Renkey

Westinghouse Hanford Co., Richland, WA

J. Pressure Vessel Tech., Trans. ASME, 107 (4), pp 366-372 (Nov 1985) 13 figs, 9 refs

KEY WORDS: Pipelines, nuclear reactor components, Damping coefficients, Seismic response

Liquid Metal Fast Breeder Reactor pipe systems typically utilize a thicker insulation package than that used on water plant pipe systems. They are supported with special insulated pipe clamps. Mechanical snubbers are employed to resist seismic loads. Recent laboratory testing has indicated that these features provide significantly more damping than presently allowed by Regulatory Guide 1.61 for water plant pipe systems. This paper presents results of additional in-situ vibration tests conducted on Fast Flux Test Facility pipe systems. Pipe damping values obtained at various excitation levels are presented. Effects of filtering data to provide damping values at discrete frequencies and the alternate use of a single equivalent modal damping value are discussed. These tests further confirm that damping in typical LMFBR pipe systems is larger than presently used in pipe design.

86-1076

Comparison and Evaluation of Analytical Structural Solutions with EPRI Safety Valve Test Results

L.C. Smith, T.M. Adams

Westinghouse Electric Corporation, Pittsburgh, PA

J. Pressure Vessel Tech., Trans. ASME, 107 (4), pp 380-386 (Nov 1985) 16 figs, 6 tables, 7 refs

KEY WORDS: Pipelines, Nuclear reactor components, Temperature effects, Testing techniques

Of concern in this paper is the operability of the safety valves and the acceptability of the downstream piping when subjected to the dynamic thermal hydraulic loadings associated with transients. To aid in this verification process the Electric Power Research Institute conducted an extensive program testing different safety valves subjected to varying operating conditions. Downstream piping loads associated with the various loading cases were also measured. This paper presents and compares analytically determined solutions for the structural response of the test configuration to actual test results. A brief description of the methods used to generate the thermal hydraulic loads is presented but the major emphasis is on the piping dynamic response. Discussed are the piping and support modeling techniques, the dynamic solution methods and the load application methods employed. Analytically calculated piping stresses, support loads, displacements, and valve nozzle loads are compared to the test results.

86-1077

Further Considerations for Damping in Heavily Insulated Pipe Systems

M.J. Anderson, M.R. Lindquist, L.K. Severud

Hanford Engrg. Dev. Lab., Richland, WA

Rept. No. HEDL-SA-3258-FP, CONF-850670-7, 14 pp (Jan 1985) ASME Pressure Vessel and Piping Div. Conf., New Orleans, LA (Jun 24, 1985) DE85008494/GAR

KEY WORDS: Pipelines, Damping coefficients, Seismic design

Over the past several years a body of test data has been accumulated which demonstrates that damping in small diameter heavily insulated pipe systems is much larger than predicted. This data is generally based on pipe systems using a stand-off insulation design with a heater annulus. Additional tests have now been completed on similar pipe systems using a strap-on insulation design without the heater annulus. Results indicate come reduction in damping over the stand-off designs. Test data has also been obtained on a larger sixteen-inch diameter heavily insulated pipe system. Results of these two additional test series are presented. Revised damping values for seismic design of heavily insulated pipe systems are then recommended.

86-1078

Vibration Transmissibility Characteristics of Reinforced Viscoelastic Pipes Employing Complex Moduli Master Curves

S.O. Oyadiji, G.R. Tomlinson
Univ. of Manchester, Manchester, England
J. Sound Vibr., 102 (3), pp 347-367 (Oct 8, 1985) 15 figs, 30 refs

KEY WORDS: Pipes, Viscoelastic properties, Reinforced structures, Vibration transfer

Fibre and wire reinforced flexible viscoelastic pipes are used in situations where their static and dynamic characteristics provide much better performance than metallic pipes. Because of their vibration and shock attenuation characteristics, viscoelastic pipes are used as flexible conduit in applications where it is desirable to minimize the transmission of vibration and structural-borne sound to the surroundings. In analyzing the vibration and structure-borne sound transmission and the vibrational power flow through systems that incorporate such pipes, knowledge of the mathematical models that satisfactorily predict the vibration transmissibility characteristics of the viscoelastic pipes is advantageous. It is shown that the use of the frequency and temperature dependent complex moduli of these pipes with the elementary and the more exact theories of the propagation of axial and flexural vibration through viscoelastic rods and beams provides satisfactory prediction of the vibration transmissibility characteristics of the reinforced viscoelastic pipes.

86-1079

Determination of the Complex Moduli of Viscoelastic Structural Elements by Resonance and Non-Resonance Methods

S.O. Oyadiji, G.R. Tomlinson
Univ. of Manchester, Manchester, England
J. Sound Vib., 101 (3), pp 277-298 (Aug 8, 1985) 15 figs, 2 tables, 18 refs

KEY WORDS: Pipes, Structural members, Viscoelastic properties, Complex modulus

The successful prediction of the vibration transmissibility characteristics of viscoelastic structural elements is strongly dependent upon the use of fairly accurate estimates of the complex moduli, often they are frequency and temperature dependent functions. Two methods, namely the standing wave resonance and the non-resonance (dynamic stiffness) methods are used to investigate frequency and temperature dependent characteristics of the complex Young's modulus of a composite viscoelastic pipe. It is shown that in the case of the standing wave resonance method, the use of the simple classical frequency equation for the determination of the complex modulus of a viscoelastic prismatic element from the modal values of frequency and transmissibility results in an absolute error of less than 8% for loss factors of up to 0·4. Also, it is shown that as the loss factor increases the number of modes for which the classical frequency equation is applicable decreases and criteria for establishing the range of validity of the classical frequency equation are described. Complex moduli data obtained from experimental tests are then used with the method of reduced variables to produce master curves and equations of reduced dynamic Young's modulus and loss factor which cover many decades of frequency.

86-1080

Pipe Whip — Bounding the Required Restraint Capacity

R. Peek
California Institute of Technology, Pasadena, CA
J. Pressure Vessel Tech., Trans. ASME, 107 (4), pp 356-360 (Nov 1985) 5 figs, 12 refs

KEY WORDS: Pipe whip restraints, Nuclear reactor components

Energy balance methods used for the design of pipe whip restraints are based on the solution for the motion of a rigid-plastic pipe before impact against the restraint. Energy balance methods are not necessarily conservative because the plastic hinge which forms in the pipe moves after impact on the restraint and elastic pipe deformations are not considered. Here, upper and lower bounds to the required restraint capacity are derived. In contrast to finite element methods, which are very time-consuming, the upper and lower bounds can be evaluated by simple hand calculations. Another advantage is that the required restraint capacity is calculated directly. No trial and error design is required. A numerical example shows that for a typical pipe and restraint, the upper and lower bounds differ by as little as 20 percent.

DUCTS

86-1081
Self-Adaptive Broadband Active Sound Control System
A. Roure
Centre National de la Recherche Scientifique, Marseille Cedex, France
J. Sound Vib., 101 (3), pp 429-441 (Aug 8, 1985) 10 figs, 8 refs

KEY WORDS: Acoustic absorption, Active noise control, Ducts, Air conditioning equipment

The principle and performance of a broadband active sound control system in an air-conditioning duct is described. The system presented, which is designed for industrial use, is self-adaptive thanks to a programmable digital filter. It is possible to obtain attenuations of between 20 and 25 dB over a frequency band from several tens of Hz up to the first transverse mode of the duct. Its self-adaptive property means that fully equipped and preset sections can be built in the laboratory and can then be inserted on site in the same way as mufflers.

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION

86-1082
Cylindrical Sound Wave Generated by Shock-Vortex Interaction
H.S. Ribner
Univ. of Toronto, Downsview, Canada
AIAA J., 23 (11), pp 1708-1715 (Nov 1985) 12 figs, 23 refs

KEY WORDS: Sound waves, Wave generation, Fluid-induced excitation, Turbulence

The passage of a columnar vortex broadside through a shock is investigated. This has been suggested as a crude, but deterministic, model of the generation of shock noise by the turbulence in supersonic jets. The plane sound waves produced by each shear wave/shock interaction are recombined in the Fourier integral.

86-1083
"A Hole Spoils a Wall" — Acoustic Analysis of Sound Transmission Through Slits by the Theory of Diffraction
G. Rosenhouse
Technion-Israel Inst. Technol, Haifa, Israel
Acustica, 58 (4), pp 189-195 (Sept 1985) 6 figs, 3 tables, 5 refs

KEY WORDS: Sound waves, Wave transmission, Wave diffraction, Openings

A numerical methodology of solving sound transmission from a sound source to a receiver via an arbitrarily shaped aperture is the object of the paper. This specific method gives the reader insight into the physical nature of the diffraction problem. The method combined Kirchhoff-integral and "Z-lines method" into a technique which enables investigation of interference effects in domains where discrete frequencies dominate. Consequently, overall energy considerations will not suffice. The acoustic effect of arbitrarily shaped plane slits or screens with any absorption may be easily handled, taking into account phase shifts. Numerical examples illustrate rigorously the rule of thumb of the consultants in acoustics: "A hole spoils a wall".

86-1084
Model Studies of Acoustic Propagation Over Contoured, Finite Impedence Ground
D.A. Hutchins, H.W. Jones, L.T. Russell
Queen's Univ., Kingston, Ontario, Canada
Acustica, 58 (4), pp 234-242 (Sept 1985) 11 figs, 7 refs

KEY WORDS: Sound waves, Wave propagation, Ground surface

A scale modeling technique has been used to determine excess attenuation data for acoustic propagation over ground surfaces with various topographic features. The model surface had an impedance and flow resistivity which matched closely that of grass-covered ground outdoors. The results indicate that interference effects are important in many situations, including some where the source is on the ground.

86-1085
Mode Filters and Steered Arrays
D.E. Weston
Admiralty Research Establishment, Portland, England
J. Sound Vib., 102 (3), pp 423-430 (Oct 8, 1985) 3 figs, 1 table, 7 refs

KEY WORDS: Underwater sound, Sound waves, Wave propagation

A vertical acoustic array in shallow water may be steered to one of the equivalent plane waves constituting a given mode, and will then couple well to that mode. Consideration of disparate impermeable boundaries shows that the half-power law is sometimes far from exact. Several extensions of these ideas are discussed, and for practical conditions the half-power law is a good approximation. A second half-power law indicated that the steered columnar array can receive about half the power in a mode.

86-1086
Background Noise Effects on the Measurement of Sound Power of Small Machines Using Sound Intensity Techniques
J. Buffa, M.J. Crocker
General Motors Corporation, Flint, MI
Noise Control Engrg. J., 25 (1), pp 4-11 (July/Aug 1985) 13 figs, 16 refs

KEY WORDS: Sound power levels, Acoustic intensity method, Two microphone technique

This paper describes an investigation of the effects of varying amounts of background noise on sound power measurements made using the two microphone sound intensity approach. Two sets of measurements were taken on machine sources: one set at a distance of approximately 0.5 m and the other set very close to the sources. The results show that the sound intensity method is a viable technique for measuring the sound power of a source and that certain indicators can be used to show when sound power results are unreliable.

SHOCK EXCITATION

86-1087
Stochastic Analysis of the Seismic Response of Secondary Systems
K.S. Smith
California Inst. of Tech., Pasadena, CA
Ph.D. Thesis, Rept. No. EERL-85-1, 179 pp (1985) PB85-240497/GAR

KEY WORDS: Equipment structure interaction, Seismic response

The thesis is concerned with the earthquake response of light equipment in structures. The motion of the ground during an earthquake is represented as a stochastic process in order to reflect uncertainty in the prediction of such motion. A number of different stochastic earthquake models are considered, and analytical methods are described for these models.

86-1088
Response Maxima of a SDOF System Under Seismic Action
M. Di Paola, G. Muscolino
Universita di Palermo, Palermo, Italy
ASCE J . Struc. Engrg., 111 (9), pp 2033-2046 (Sept 1985) 9 figs, 23 refs

KEY WORDS: Single degree of freedom systems, Seismic excitation, Statistical analysis

A semi-empirical method for the evaluation of the statistical characteristics of the mean, variance and the maximum response peak of a single degree of freedom linear system under seismic action is presented. The non-stationary ground motion is modeled filtering a white Gaussian random noise and enveloping the filtered noise by a deterministic shaping function. The linear differential equations for the determination of the spectral moments are examined and a closed-form solution given. Extensive studies by means of digital simulation are made and the proposed semi-empirical formulation is compared with the other approximate methods available in the literature within the framework of the first passage problem.

86-1089
Dislocation Kinetics Behind Shear Shocks
R.B. Stout, G.D. Anderson
Lawrence Livermore National Lab., CA
Rept. No. UCRL-92255, CONF-850736-24, 6 pp (June 1985) (Amer. Phys. Soc. Topical Conf. Shock Waves in Condensed Matter, Spokane, WA, July 22, 1985) DE85014811/GAR

KEY WORDS: Shock wave propagation, Shear waves

High velocity oblique impact experiments result in both compression and shear shock waves. Behind the shear shock wave the particle velocity is transverse to the shock front. At large transverse particle velocities, dislocation kinetics can contribute a portion of the velocity. Based on a kinematic and thermodynamic model of dislocation kinetics, an analysis is made of the transverse strain and velocity behind a shear shock. Kinematics of dislocations in transverse motion behind the shock is formulated. A solution is given for an ideal case where the dislocation density function propagates as a pulse behind the shear shock.

86-1090
Investigation to Optimize the Passive Shock Wave/Boundary Layer Control for Supercritical Airfoil Drag Reduction
H.T. Nagamatsu, R. Dyer
Rensselaer Polytechnic Inc., Troy, NY
Rept. No. NASA-CR-175788, 33 pp (Dec 1984) N85-26665/8/GAR

KEY WORDS: Airfoils, Shock wave-boundary layer interaction, Wind tunnel testing

The passive shock wave/boundary layer control for reducing the drag of 14%-thick supercritical airfoil was investigated in the 3 in x 15.4 in. RPI Transonic Wind Tunnel with and without the top wall insert at transonic Mach numbers. Top wall insert was installed to increase the flow Mach number to 0.90 with the model mounted on the test section bottom wall. Various porous surfaces with a cavity underneath were positioned on the area of the airfoil where the shock wave occurs.

VIBRATION EXCITATION

86-1091
Frequency Control and its Effect on the Dynamic Response of Flexible Structures
V.B. Venkayya, V.A. Tischler
Air Force Wright Aeronautical Labs., Wright-Patterson Air Force Base, OH
AIAA J., 23 (11), pp 1768-1774 (Nov 1985) 5 figs, 7 tables, 11 refs

KEY WORDS: Optimum control theory, Structural modification techniques, Optimization, Vibration control

The effect of structural optimization on optimal control design is studies in this paper. Structural optimization was treated as a problem of mass minimization with constraint on the open-loop frequency. The quadratic performance index, involving the state and control variables, was used in the design of the control system. A control system with only full-state feedback was considered. A procedure for generating the state and control weighting matrices by structural dynamics programs was outlined. By introducing simple scaling parameters, the weighting matrices were used effectively to achieve the desired control objectives. A number of case studies using a simple truss structure were made. Vibration suppression with only initial disturbances was considered. The conclusion was that modification of the structural parameters (stiffness and structural mass) did not significantly alter the control design in this study.

86-1092
A New Technique for the Investigation of Stick-Slip
A.G. Plint, M.A. Plint
Cameron-Plint Tribology Ltd., Berkshire, U.K.
Trib. Intl., 18 (4), pp 247-249 (Aug 1985) 7 figs

KEY WORDS: Stick-slip response

The stick-slip phenomenon has been investigated using an existing high frequency friction machine at very low speed. Static friction was found to vary with frequency and to approach a maximum as the length of time during which the contacting surfaces were at rest increased. This was thought to be due to a squeeze film effect leading to increasing asperity contact.

86-1093
Effects of Vortex-Resonance on Nearby Galloping Instability
A. Bokaian, F. Geoola

Earl and Wright Ltd., London, UK
ASCE J. Engrg. Mech., 111 (5), pp 591-608 (May 1985) 16 figs, 2 tables, 15 refs

KEY WORDS: Fluid-induced excitation, Prismatic bodies, Vortex induces excitation, Galloping

Measurements are presented on the response of a rigid smooth rectangular prism, free to oscillate laterally against linear springs in a uniform flow. The prism was of side ration 1:2 with the broader side facing the flow direction. The experiments also encompassed wake observations behind the prism when fixed, as well as determination of the lift forces on the fixed prism as a function of angle of flow attach. Dynamic tests showed that an increase in structural damping generally causes the instability to begin at a higher flow speed.

86-1094
The Dynamics of Vortex Amplifiers. Part 1: Analytical Model
E.E. Kitsios, R.F. Boucher
Univ. of Sheffield, Sheffield, England
J. Dynam. Syst., Meas. Control, Trans. ASME, 107 (3), pp 176-181 (Sept 1985) 11 figs, 9 refs

KEY WORDS: Vortex amplifiers, Fluid-induced excitation, Mathematical models

A semi-empirical technique for the dynamic modeling of vortex amplifiers is demonstrated with reference to one particular vortex amplifier geometry. The model parameters are determined explicitly from the amplifier static characteristics and geometry except for two which are estimated from measurements of the amplifier's dynamic response. The two are time constants associated with the chamber time delay and the vortex rotational inertia. The model is linearized about a working point and is presented in terms of an admittance matrix. The paper is continued in Part 2 where two of the amplifier's transfer admittances are measured experimentally and compared with the model predictions.

86-1095
The Dynamics of Vortex Amplifiers. Part 2: Dynamic Measurements and Comparison with Model Predictions
R.F. Boucher, E.E. Kitsios
Univ. of Sheffield, Sheffield, England
J. Dynam. Syst., Meas. Control, Trans. ASME, 107 (3), pp 182-186 (Sept 1985) 11 figs, 4 refs

KEY WORDS: Vortex amplifiers, Fluid-induced excitation, Measurement techniques

A general experimental procedure is described for determining the linearized transfer admittances of a vortex amplifier. Flow response at the ports to a measured pressure perturbation applied to any one of them was obtained by hot wire anemometer. Self and transfer admittances were determined using a dual channel spectrum analyzer. The difficulties involved in such experiments are discussed. Measurements at two working points compare well with those predicted by the theoretical model developed in Part 1 of this paper.

86-1096
An Experimental Study of the Reflection and Transmission of Flexural Waves at Discontinuities
J.F. Doyle, S. Kamle
Purdue Univ., West Lafayette, IN
J. Appl. Mech., Trans. ASME, 52 (3), pp 669-673 (Sept 1985) 6 figs, 1 table, 7 refs

KEY WORDS: Discontinuity-containing media, Flexural waves, Wave transmission, Wave reflection, Fast Fourier transform

The research reported is the study of the transmission and reflection characteristics of flexural waves at structural discontinuities. A Fast Fourier Transform (FFT) computer algorithm is used to characterize the dispersive flexural waves. The incident wave is propagated through two types of discontinuities namely, a stepped beam and the free end of a beam. At each stage, comparison with experimental results are made.

MECHANICAL PROPERTIES

DAMPING

86-1097
Critical Damping in Complex Structures and Control Systems
D.J. Inman
State Univ. of New York at Buffalo, NY

(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp AAA-1 - AAA-12, AD-A152 547) AD-P004 731/6/GAR

KEY WORDS: Critical damping, lumped parameter method, Continuous parameter method, Finite element technique

This work examines the concept of critical damping normally defined for single degree of freedom systems as applied to more complex models of structures and their control systems.

86-1098
Vibration Damping Analysis Using the Finite Element Method
R.A. Brockman
Dayton Univ., Dayton, OH
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp II-1 -II-10, AD-A152 547) AD-P004 715/9/GAR

KEY WORDS: Vibration damping, Finite element technique, Computer programs

This paper describes some of the current solution methodology for finite element analysis of problems in vibration damping, and addresses several common questions regarding the differences between methods and computer programs. The discussion is intended for non-specialists in finite element methods, and focuses on basic questions and principles in the use of finite elements for damping design and analysis.

86-1099
Some Musings on How to Make Damping a Creative Force in Design
J.W. Mar
Massachusetts Inst. of Tech., Cambridge, MA
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp A-1 -A-22, AD-A152 547) AD-P004 685/4/GAR

KEY WORDS: Damping characteristics, Design techniques

Some suggestions are advanced toward making damping a complete technology so that damping can become a creative force in structural design. Examples cited include the invention of mechanisms to enhance and control damping, the testing of structural joints in simulated zero-g, the measurement of material damping without aerodynamic forces and the testing of structures in the zero-g and high vacuum of space.

86-1100
Thermoelastic and Electromagnetic Damping Analysis
U. Lee
Stanford Univ., Stanford, CA
AIAA J., 23 (11), pp 1783-1790 (Nov 1985) 6 figs, 27 refs

KEY WORDS: Thermoelasticity, Electromagnetic damping, Beam-plate systems

The thermoelastic damping due to thermal currents and the electromagnetic damping due to electric conduction currents of vibration solids are discussed. The effects of structural and geometrical constraints on damping loss factors are investigated. Also, optimum conditions for the maximum damping, which may be useful on the stage of system design, are investigated. It is found that damping loss factors are generally dependent upon structural and geometrical configurations. An analogy exists between thermoelastic damping and electromagnetic damping, showing Debye curves with Debye peaks. Standing transverse waves are likely to achieve larger damping than standing dilatational waves in the presence of a magnetic field. Electromagnetic damping in ferro-magnetic material bodies is found to be considerable in high field. The influence of thermoelastic damping on aeroelastic stability of beam plates is investigated. This research strongly suggest that thermoelastic damping improves the aeroelastic stability of beam plates.

86-1101
Approach to the Sizing of Discrete Viscous Structural Dampers Using an Extension of the Finite Element Approach and Modal Strain Energy
R.B. Rich, E.C. Dalton
Martin Marietta Aerospace, Denver, CO
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp BBB-1 - BBB-21, AD-A152 547) AD-P004 732/4/GAR

KEY WORDS: Viscous damping, Finite element technique, Modal strain energy method

A method for determining viscous damper values and damper locations for a structure which has particular damping requirements is presented in this paper. The method is intended as a starting point in a design process. The finite element approach and concept of modal strain energy are heavily relied upon. To illustrate the solution sequences, a sample problem is included in the

report. The method was applied to a large space-based telescope in which damping of optical support structures is critical for tracking and pointing accuracy. The results of the sample problem indicated that the method will yield the desired amount of damping in a structure provided that the complex mode shapes do not significantly deviate from the classical mode shapes.

86-1102
Sizing of Discrete Viscous Dampers on a Flexible Body in the Presence of a Fixed Controller
G.R. Rapacki, R.B. Rice
Martin Marietta Aerospace, Denver, CO
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp ZZ-1 -ZZ-28, AD-A152 547) AD-P004 730/8/GAR

KEY WORDS: Viscous damping, Spacecraft

The authors investigated the effects of discrete viscous dampers on a spacecraft's rigid body control loop. The damper's affect on the open loop gain and phase margins, the shape of the open loop gain-phase plot and the flexible body dynamics were determined as a function of the viscous damper's strength and the mass connected to the damper. The damper was sized for those configurations where the added damper inproved the system robustness.

86-1103
Elastical Characteristics of Antivibrating Rubber Elements
B. Polidor
Building Research Institute - INCERC, Bucharest, Romania
Dyn. of Mach. Foundations, Proc. Symp. Bucharest, Romania, pp 153-160 (Oct 22-24, 1985) 4 figs, 4 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Elastomeric dampers, Machine foundations, Elastic properties

This paper presents the experimental results on the establishment of the dynamic rigidity coefficient and the dynamic Young's modulus in terms of real static and dynamic loading for three types of Romanian rubber dampers.

86-1104
Experimental Study of Passive Damping and Active Control of Large Space Structures
S.S. Simonian, C.S. Major, R. Gluck
TRW Space and Technology Group, Redondo Beach, CA
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp YY-1 - YY-41, AD-A152 547), AD-P004 729/0/GAR

KEY WORDS: Viscoelastic damping, Spacecraft, Modal strain energy method, Finite element technique

This report presents a methodology for incorporating passive dampers in large space systems design. The methodology focuses on modular, discrete viscoelastic dampers which are integrally designed into the structure. The report describes the application of the methodology to the TRW LSS Experiment. Performance evaluation of the damped structured design was obtained using the Modal Strain Energy technique, based on finite element models in Program NASTRAN. A parameter variation study of the dampers' performance was conducted, yielding, for the first three modes of a nominal damper configuration, an augmented modal damping ratio of 9 percent of critical damping.

86-1105
Finite Element Design of Viscoelastically Damped Structures
C.D. Johnson, D.A. Kienholz, E.M. Austin, M.E. Schneider
CSA Engrg., Inc., Palo Alto, CA
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp HH-1 - HH-28, AD-A152 547), AD-P004 714/2/GAR

KEY WORDS: Viscoelastic damping, Finite element technique, Model strain energy method

This paper describes four methods for the finite element analysis of structures containing a viscoelastic material. These methods fall into the categories of methods for damping treatment selection of methods for response prediction. The main emphasis of this paper is directed towards the Model Strain Energy (MSE) method. The MSE method uses normal mode techniques and, therefore, is an efficient method for the design of viscoelastically damped structures. The MSE method, implemented by finite element techniques, will aid analysts in selecting the location of the damping treatment, selecting the damping treatment, predicting the model damping

factors, and predicting the response of the structure. A discussion of finite element modeling methods for structures containing viscoelastic materials is included. Two structures are discussed for which viscoelastic damping treatments were designed. Comparisons of predicted and measured modal damping and frequencies are given.

86-1106
Improvement of Damping in Fiber Reinforced Polymer Composites
R.F. Gibson, S.A. Suarez, L.R. Deobald
Idaho Univ., Moscow, ID
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp S-1 -S-21, AD-A152 547) AD-P004 702/7/GAR

KEY WORDS: Viscoelastic damping, Composite materials, Fiber composites

This paper presents preliminary experimental results from a study of damping in aligned discontinuous fiber reinforced polymer composites. The experiments were conducted in order to verify a previously developed theoretical model. It predicted that discontinuous fiber reinforcement should enhance the shear-induced linear viscoelastic damping effect in the polymer matrix material. Data for graphite/epoxy and aramid/epoxy composites show that, as predicted, very low fiber aspect ratios are required to produce significant improvement in damping, and that damping also increases markedly with increasing vibration frequency at these low aspect ratios.

86-1107
Measurement of Damping of Graphite Epoxy Materials
M.J. Crocker
Auburn Univ., Auburn, AL
Rept. No. NASA-CR-175793, 15 pp (May 1, 1985) N85-26925/6/GAR

KEY WORDS: Material damping, Graphite, Measurement techniques

During this period damping measurements were made on the cylindrical graphite epoxy specimen using the forced-vibration test method. The specimen was carefully mounted directly on the shaker through the supporting ring and the impedance head. This was done to simulate an idealized free-free boundary condition at the two edges. The damping ratio value and the natural frequency (first mode) obtained in this experiment were 0.13% and 508.75 Hz respectively. In order to check the damping induced by the supporting ring, measurements were made with the top half of the ring removed. The specimen then was supported only by the bottom half of the ring (half ring).

86-1108
Damping in Metal-Matrix Composites: Measurement and Modeling
H.M. Ledbetter, S.K. Datta
National Bureau of Standards, Boulder, CO
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp W-1 -W-18, AD-A152 547) AD-P004 705/0/GAR

KEY WORDS: Material damping, Composite materials, Measurement techniques, Mathematical models

Both experimentally and theoretically, this report considers attenuation, alpha, of elastic waves in a composite consisting of elastic reinforcing particles dispersed in an elastic matrix. The authors consider only geometrical attenuation caused by scattering from particles.

86-1109
Damping Behavior of Metal Matrix Composites
M.S. Misra, P.D. LaGreca
Martin Marietta Aerospace, Denver, CO
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp U-1 -U-13, AD-A152 547) AD-P004 704/3/GAR

KEY WORDS: Material damping, Composite materials, Fiber composites

Discontinuous and continuous fiber reinforced composites were evaluated for their damping capacities and elastic moduli. In the case of graphite/aluminum and graphite/magnesium, the damping factor increases significantly in the transverse direction and slightly in the longitudinal direction. Efforts were made to explain the observed behavior to the fiber matrix and the diffusion bonded interfaces present in these composites. If the interface strength is higher than that of the matrix alloy, the damping capacity remains the same. However, if the

interfaces are the weaker areas, i.e., areas of metallurgical imperfection, the damping capacity increases.

86-1110
Composite Material Damping Using Impulse Technique
C.T. Sun, B.T. Lee, S.K. Chaturvedi
Florida Univ., Gainesville, FL
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp P-1 -P-24, AD-A152 547) AD-P004 699/5/GAR

KEY WORDS: Testing techniques, Material damping, Impulse testing, Composite materials

An experimental technique known as the impulse technique is presented for measuring the internal damping of composite materials. In order to gain confidence on the experimental data measured from this technique some improvements have been made.

86-1111
Segmenting and Mechanical Attachment of Constrained Viscoelastic Layer Damping Treatments for Flexural and Extensional Waves
E.M. Kerwin, P.W. Smith
Bolt Beranek and Newman, Inc., Cambridge, MA
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp KK-1 - KK-24, AD-A152 547) AD-P004 717/5/GAR

KEY WORDS: Layered damping, Viscoelastic damping, Flexural waves, Extensional waves

Segmenting (periodic interruption) increases the effectiveness of a constrain-layer damping treatment for flexural waves at frequencies below the peak damping for the continuous system. The interruption of the constraining layer results in induced strains in the viscoelastic layer, giving higher dissipation than for the continuous system. There is an optimum segment length for a given treatment. Discusses the application of segmented constrained layers to the damping of extensional waves.

86-1112
Results of Finite Element Analysis of Damped Structures
M.F. Kluesener
Dayton Univ., Dayton, OH
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp JJ-1 -JJ-12, AD-A152 547) AD-P004 716/7/GAR

KEY WORDS: Layered damping, Finite element technique

Finite Element Analysis is being used increasingly to model passive damping configurations on integrally damped structures. However, the modeling of passive damping designs on complex structures poses two problems. First of all, the thin damping layers generally result in high aspect rations of the 3D solid elements representing the damping system. Secondly, if a multilayered damping system is modeled, there are a large number of degrees-of-freedom which results in a costly computer run. This paper discusses ways to reduce the number of elements representing the damping system and the accuracy of the damping prediction using high aspect ratios. Experimental tests and corresponding finite element analysis of a double constrained layer damped cantilever plate show that aspect ratios up to 1000:1 yield very accurate results.

86-1113
Design Evaluation and Field Qualification of a Damping System for an Auxiliary Power Unit
M.L. Drake
Dayton Univ., Dayton, OH
(Vibr. Damping Workshop Proc., Long Beach, Ca, Feb 27-29, 1984, pp MM-1 - MM-18, AD-A152 547) AD-P004 719/1/GAR

KEY WORDS: Power plants, Turbine engines, Fatigue life, Vibration dampers

A turbine engine used to operate an auxiliary power unit was incurring resonant vibration induced fatigue failures in the inlet guide vanes. Field test data revealed high stress levels at frequencies corresponding to the second bending and second torsional resonances. The operational environment required a damping system to be functional over the temperature range of -50 F and 150 F. The damping system had to survive the high airflow and erosion environment associated with the inlet of the engine and also had to be field installable. A computer aided design procedure was used to develop the required damping design. The final design was proof tested in the laboratory and demonstrated in 86 percent stress reduction.

86-1114
Research on Friction Damping in Jet Engines at Carnegie-Mellon University
J.H. Griffin, J. Bielak
Carnegie-Mellon Univ., Pittsburgh, PA
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp M-1 -M-13, AD-A152 547) AD-P004 696/1/GAR

KEY WORDS: Jet engines, Coulomb friction, Finite element technique

This paper discussed the results of recent research on friction damping at Carnegie-Mellon University. Topics include: mistuning/friction interaction, flutter stabilization, the use of the finite element method to calculate the forced response of structures containing friction interfaces, and improved methods for modeling friction.

FATIGUE

86-1115
Prediction of Threshold and Ultra-Low Fatigue Crack Growth Rates
L. Guerra Rosa, C.M. Branco, J.C. Radon
CEMUL, Technical Univ. of Lisbon, Lisbon, Portugal
Intl. J. Fatigue, 7 (4), pp 183-189 (Oct 1985) 12 figs, 4 tables, 20 refs

KEY WORDS: Fatigue life, Crack propagation, Prediction techniques

A model was derived to predict the true threshold value for fatigue crack growth in the absence of crack closure. The model, based only on the tensile and cyclic properties of the material, was successfully verified against a set of experimental data on medium and high strength steels and one aluminium alloy. Good agreement with experimental results was obtained using a fatigue crack growth rate equation based on the same model.

86-1116
Automatic Near-Threshold Fatigue Crack Growth Rate Measurements at Liquid Helium Temperature
R.L. Tobler, Y.W. Cheng
National Bureau of Standards, Boulder, CO
Intl. J. Fatigue, 7 (4), pp 191-197 (Oct 1985) 9 figs, 2 tables, 22 refs

KEY WORDS: Fatigue life, Crack propagation, Fatigue tests, Measurement techniques

The development of a fully automated test apparatus for near-threshold fatigue crack growth rate measurements in a liquid helium environment is described, and some initial results for AISI 300 series stainless steels are presented. Experimental apparatus consists of a servohydraulic test machine and a cryostat, complete with a minicomputer, a programmable arbitrary waveform generator, a programmable digital oscilloscope and a fully automatic liquid helium refill system. The technique uses 6.4 mm thick compact specimens subjected to systematically decreasing loads, with 24 h operation at 40 Hz, the crack growth being continuously monitored by specimen compliance measurements.

86-1117
The Fatigue Threshold, Surface Condition and Fatigue Limit of Steel Wire
I. Verpoest, E. Aernoudt, A. Deruyttere, M. DeBondt
Katholieke Universiteit Leuven, Heverlee, Belgium
Intl. J. Fatigue, 7 (4), pp 199-214 (Oct 1985) 25 figs, 4 tables, 37 refs

KEY WORDS: Fatigue life, Wire, Steel

To test the hypothesis that fatigue cracks in drawn, pearlitic steel wire propagate from pre-existing surface defects which can be treated as cracks, the fatigue limits of five different wires have been statistically determined.

86-1118
A Method to Assess Notched Fatigue Behaviour
A. Esin, B. Uzuner
Middle East Technical Univ., Turkey
Intl. J. Fatigue, 7 (4), pp 215-218 (Oct 1985) 3 figs, 5 tables, 12 refs

KEY WORDS: Fatigue life, Photoelastic analysis

A method to estimate the strength reduction factors (K_f) of notched fatigue specimens is presented. It is shown that the influence of the notch geometry on fatigue life can be assessed by photoelastic analysis. A simple mathematical expression to estimate the value of K_f has been put forward. The validity of the expression has been verified experimentally by comparing against fatigue test results.

86-1119
Flexural Fatigue Resistance of Ultra-High Molecular Weight Polyethylene at Ambient and Low Temperature
H. Yelle, R. Gauvin, G. Narvaez
Ecole Polytechnique de Montreal, Montreal, Quebec, Canada
Intl. J. Fatigue, 7 (4), pp 219-223 (Oct 1985) 9 figs, 1 table, 12 refs

KEY WORDS: Fatigue tests, Temperature effects

Specimens of ultra-high molecular weight polyethylene have been subjected to flexural fatigue tests at -40 C and 23 C, and the temperature of some of the specimens recorded throughout the test. It is found that when the specimen life exceeds 10^6 cycles, the temperature of the specimen stabilizes.

86-1120
Measurement and Analysis of Critical Crack Tip Processes during Fatigue Crack Growth
D.L. Davidson, S.J. Hudak, R.J. Dexter
Southwest Research Inst., San Antonio, TX
Rept. No NASA-CR-172597, 108 pp (June 1985)
N85-32342/6/GAR

KEY WORDS: Fatigue life, Crack propagation

The mechanics of fatigue crack growth under constant-amplitudes and variable-amplitude loading were examined. Critical loading histories involving relatively simple overload and overload/underload cycles were studied to provide a basic understanding of the underlying physical processes controlling crack growth. The material used for this study was 7091-T7E69, a powder metallurgy aluminum alloy. Local crack-tip parameters were measured at various times before, during, and after the overloads, these include crack-tip opening loads and displacements, and crack-tip strain fields. The sensitivity of the analytical model to constant-amplitude fatigue crack growth rate properties and to through-thickness constrain are studied.

86-1121
Crack Growth Analyses and Correlations for Attachment Lugs
K. Kathiresan, T.R. Brussat, J.L. Rudd
Air Force Wright Aeronautical Lab., Wright-Patterson Air Force Base, OH
J. Aircraft, 22 (9), pp 818-824 (Sept 1985) 11 figs, 1 table, 31 refs

KEY WORDS: Fatigue life, Crack propagation

A method of damage tolerance analysis for corner cracks in attachment lugs is presented. It is correlated with constant-amplitude fatigue crack growth test results. In the analysis, stress intensity factor solutions for through-the-thickness cracks, obtained from the Green's function method and modified by the use of correction factors, are applied to corner cracks, including transition to a through-the-thickness crack. The accuracy of the analysis is demonstrated through correlations with test results for 24 axially loaded, straight lugs with tiny initial corner cracks. Tests cover three lug shapes, two materials (4340 steel and 7075-T651 aluminum), and two stress ratios, and all tests are replicated.

86-1122
Dynamic Fracture Under Normal Impact Loading of the Crack Faces
K.-S. Kim
Univ. of Illinois, Urbana, IL
J. Appl. Mech., Trans. ASME, 52 (3), pp 585-592 (Sept 1985) 8 figs, 2 tables, 17 refs

KEY WORDS: Fracture properties

Results of experiments on crack-face impact are presented. The transient stress-intensity factor variation of a crack has been traced by the Stress-Intensity Factor Tracer. The crack-face impact loading was produced by an electromagnetic force induced by a square pulse of an electric current flowing through a copper strip inserted in the saw-cut crack of a Homalite 100 plate specimen. The current flowed in opposite directions in the two portions of the copper strip, between the crack faces, causing them to repel each other. The short-time and the long-time behavior of the transient stress-intensity factor variation under the impact loading have been carefully investigated. Brittle dynamic initiation of crack extension and the stress-intensity variation of a running crack have been also examined. The experimental results have been compared with theoretical predictions based on Freund's crack-face concentrated load solution. The agreement between the theory and the experiment is excellent. In this study, the various waves generated by the loading are shown to play different roles in transmitting the load to the crack tip.

86-1123
A Continuum Model for Dynamic Tensile Microfracture and Fragmentation
L. Seaman, D.R. Curran, W.J. Murri

SRI International, Menlo Park, CA
J. Appl. Mech., Trans. ASME, 52 (3), pp 593-599 (Sept 1985) 6 figs, 23 refs

KEY WORDS: Fracture properties, Continuum mechanics, Mathematical models

A continuum model for dynamic tensile cleavage fracture and fragmentation has been developed by detailed simulation of brittle fracture processes in elastoplastic materials. The model includes processes for nucleation of microcracks, stress-dependent growth, coalescence and fragmentation, and stress relaxation caused by the developing damage. Fracturing is characterized by a crack density with a distribution of sizes at each material point.

WAVE PROPAGATION

86-1124
Dynamic Stress-Concentration Effects on Stress Waves in Composite Models with Different Fiber-End Geometries
H. Pih, Q. Bi, Y.Y. Chen, P. Ye
Univ. of Tennessee, Knoxville, TN
Exptl. Mech., 25 (3), pp 214-225 (Sept 1985) 17 figs, 11 refs

KEY WORDS: Fiber composites, Stress waves, Wave propagation

The stress-concentration effect on fiber-end geometries on the propagating stress waves in composite models was investigated by the dynamic photoelastic method. The effects of the reinforced rod or fiber-bundle ends on the dynamic birefringent patterns were analyzed by comparing the fringe patterns at the same locations in a plain model of identical contour under the same loading conditions.

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

86-1125
Is Any Free Flight/Wind Tunnel Equivalence Concept Valid for Unsteady Viscous Flow?
L.E. Ericsson
Lockheed Missiles & Space Co., Inc., Sunnyvale, CA
J. Aircraft, 22 (10), pp 915-919 (Oct 1985) 11 figs, 22 refs

KEY WORDS: Compressors, Rotors, Helicopters, Wind tunnel testing, Flight tests

An analysis is presented on the use of a free flight/wind tunnel equivalence concept derived for steady flow for simulation of the unsteady flow effects when estimating the impact of dynamic stall on the performance of axial flow compressors and helicopter rotors. Furthermore, not even a free flight/wind tunnel equivalence concept derived for unsteady inviscid flow will correctly simulate the dynamic stall characteristics.

86-1126
Shortened Modal Analysis as an Approximation in Structure Dynamics
E. Kramer
Technische Hochschule Darmstadt, Fed. Rep. Germany
Dyn. Mach. Foundations, Proc. Symp. Bucharest, Romania, pp 237-256 (Oct 22-24, 1985) 11 figs, 4 tables, 5 refs. AVAIL: Institutul Politehnic Bucuresti, Catedra de Rezistenta Materialelor, Splaiul Independentei 313, 79590 Bucuresti, Romania

KEY WORDS: Modal analysis, Harmonic excitation

The response of a system to harmonic excitation is characterized by the amplification function. In case of a modal analysis, it consists of an appropriate number of terms. By means of the relative modal static part, introduced in this paper, it is possible on the one hand to recognize which terms are important, and on the other hand to determine in a simple way rather accurate values for the resonance peaks.

86-1127
Natural Modes of Modified Structures
J.F. Baldwin, S.G. Hutton
Univ. of British Columbia, Vancouver, Canada
AIAA J., 23 (11) pp 1737-1743 (Nov 1985) 87 refs

KEY WORDS: Natural modes, Structural modification techniques

This paper presents a detailed review of structural dynamics modification techniques. The available literature is sizeable and somewhat disparate.

86-1128
Improved Extensional Modulus Measurements for Polymers and Metal Matrix Composites
W. Madigosky
Naval Surface Weapons Ctr., Silver Spring, MD
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp Q-1 -Q-12, AD-A152 547) AD-P004 700/1/GAR

KEY WORDS: Measuring instruments, Composite structures, Wave propagation, Extensional waves, Complex modulus

An improved resonance apparatus for rapid and reliable materials characterization is described. The apparatus accurately determines the propagation constants of an extensional acoustic wave by exciting a bar of material at one and by a noise source while the other is allowed to move freely. Miniature accelerometers measure the accelerations at the two locations. A dual channel Fast Fourier Transform spectrum analyzer is used to obtain the amplitude and phase response as a function of frequency from which the complex Young' modulus can be obtained. Young's modulus anc loss factor measurements have been successfully measured in materials ranging from soft polymers to rigid metal matrix composites. For viscoelastic materials the method of fractional derivatives is found to successfully model the complex modulus throughout the transition region, and suggests that the four independent constants used are indeed related to the measurable physical properties and chemical composition of the material.

86-1129
Portable Magnetic Tape Recorders for Vibration Analysis and Monitoring
N.L. Baxter, R.L. Eshleman
ABM Technical Services, Inc., Plainfield, IN
Vibrations, 1 (3), pp 4-11 (Dec 1985) 7 figs, 4 tables, 1 ref

KEY WORDS: Recording instruments

This article describes the advantages and limitations of portable magnetic tape recorders (maximum weight 20 lb or 9 kg) in vibrations analysis and monitoring. Among factors that must be considered in using tape recorders are frequency response, dynamic range, phase, and transducer used. Included in the article are a table showing characteristics of portable tape recorders currently available and a discussion of the role of transducers in successful tape recording.

86-1130
Sensor Technologies of the Future
G.R. Jordan
Marconi Res. Ctr., Chelmsford, Essex, UK
J. Physics, E: Sci. Instrum., 18 (9), pp 729-735 (Sept 1985) 4 figs, 26 refs

KEY WORDS: Measuring instruments, Detectors, Reviews

It is now widely accepted that sensors form a vital and necessary part of any measurement and control system and there have been many predictions concerning the demand for such devices. Particular needs have been identified for new forms of sensors which are rugged and reliable, have improved performance over existing devices and particularly are compatible with the extensive number of computer controlled systems which are being introduced in all industrial sectors. This paper discusses the present situation with regard to those technologies which are considered likely to play a major role in the sensors of the future. Four main sensor technologies are identified. Examples are presented to illustrate the advantages presented by each of these technologies and observations are made about the particular aspects and sensor configurations which are likely to see early exploitation.

86-1131
Sensors with Oscillating Elements
T. Gast
Universitat Berlin, Berlin, West Germany
J. Physics, E: Sci. Instrum., 18 (9), pp 783-798 (Sept 1985) 14 figs, 16 refs

KEY WORDS: Detectors, Measuring instruments

Variable frequency can be used as an information parameter in signals for measuring techniques if the measuring principle chosen favors its application, if freedom from interference is essential, transmission over long distances is necessary, or easy digital conversion is desir-

able. The variation in frequency is in general obtained from the more or less direct influence of the quantity to be measured on an oscillator parameter. Examples with various input variable and principles of conversion are presented.

DYNAMIC TESTS

86-1132

Optical Fibres in NDT: A Brief Review of Applications

B. Culshaw

Univ. of Strathclyde, Glasgow, UK

NDT Intl., 18 (5), pp 265-268 (Oct 1985) 7 figs, 6 refs

KEY WORDS: Nondestructive tests, Vibration measurement, Fiber optics, Testing techniques

This paper reviews the applications of the fibre optics in NDT. Optical fibres may be used in two modes, either as a remote light source which may be located to high precision, or as the basis of a fibre-optic sensor to monitor environmental parameters with high sensitivity. Both functions may be executed with extremely high spatial resolution, in the order of a few micrometers. Some specific examples include probes to monitor surface vibration, temperature measurement devices, embedded transducers for use especially in fibre-based materials, and as point sources for acoustic generation and remote holographic examination techniques. This paper discusses these applications and speculates on other potential applications.

86-1133

Material Damping of Carbon/Epoxy Composites by Means of Free-Free Beam Resonance Tests

D.W. Haines

Manhattan College, Bronx, NY

(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp R-1 -R-17, AD-A152 547) AD-P004 701/9/GAR

KEY WORDS: Resonance bar techniques, Composite structures, Material damping

Results are presented of a testing program which characterizes the principal (0 deg and 90 deg) damping properties of unidirectional composites incorporating Celion carbon fibers. Data for 0/ + or - 45/90s specimens are also presented. Use of free-free beam resonance tests eliminated errors introduced by support conditions. This test method also enables the determination of Young's moduli and the shear modulus in the plane of bending.

86-1134

Laboratory Vibration Schedules

Army Test and Evaluation Command, Aberdeen Proving Ground, MD

Rept. No. ITOP-1-2-601, 243 pp (May 11, 1985) AD-A155 856/8/GAR

KEY WORDS: Testing techniques, Vibration tests, Cargo transportation, Flight vehicle equipment response, Ground vehicle equipment response

This report describes two types of vibration tests conducted in the laboratory: first, a mission/field secured cargo test to simulate the transportation of Army material as secured cargo during logistical shipments; and second, an application-induced vibration test to simulate the tactical vibration environment experiences by equipment installed in/on ground vehicles or helicopters. No attempt is made to address the vibration environments for equipment installed in fixed-wing aircraft, missiles, and ships (marine equipment).

86-1135

Time Interval Damage Potential of Seismic Testing Waveforms

D.T. Tang, D. Li

Westinghouse Electric Corporation

J. Pressure Vessel Tech., Trans. ASME, 107 (4), pp 373-379 (Nov 1985) 12 figs, 1 table, 8 refs

KEY WORDS: Equipment response, Seismic tests, Testing techniques

The concept of time interval response spectrum is introduced for characterizing the damage potential or the likelihood of a waveform to cause multiple mode response. By modifying slightly a typical response spectrum calculation routine the Weighted Spectrum Mean (WSM) is determined by evaluating the area under a normalized spectrum curve. A more detailed delineation of the response peaks statistics of simple oscillators results in the development of a Damage Potential Index (DPI). Both WSM and DPI are utilized to quantify damage potential for a variety of waveforms including free field

motion and recorded testing motions. The results suggest that a useful tool has been established with only a small added effort to help design, predict, or analyze the damage potential of testing waveforms for seismic operability qualification of equipment.

DIAGNOSTICS

86-1136
Diagnosing Alternating Current Electric Motor Problems Part I: Mechanical Problems
W.R. Campbell
Arab American Oil Company, Dhahran, Saudi Arabia
Vibrations, 1 (2), pp 5-10 (Sept 1985) 13 figs, 4 refs

KEY WORDS: Diagnostic techniques, Electric motors

This two-part article describes some of the problems associated with alternating current electric motors that arise in the field and after workshop overhauls. Causes, testing procedures, and possible solutions are discussed. Mechanical problems are the topic of Part I. Part II contains descriptions of electromagnetic problems and a chart of symptoms, causes, tests, and corrections.

86-1137
Diagnosing Alternating Current Electric Motor Problems Part 2: Electromagnetic Problems
W.R. Campbell
ARAMCO, Dhahran, Saudi Arabia
Vibrations, 1 (3), pp 12-15 (Dec 1985) 1 table, 3 refs

KEY WORDS: Diagnostic techniques, Electric motors, Electromagnetic properties

This two-part article describes some of the problems associated with alternating current electric motors that arise in the field and after workshop overhauls. Causes, testing procedures, and possible solutions are discussed. Mechanical problems are the topic of Part 1. Part 2 contains descriptions of electromagnetic problems and a chart of symptoms, causes, tests, and corrections.

86-1138
Low Frequency Vibration Generated by Gear Tooth Impacts
P.D. McFadden
Aeronautical Res. Labs., Melbourne, Australia
NDT Intl., 18 (5), pp 279-282 (Oct 1985) 3 figs, 7 refs

KEY WORDS: Diagnostic techniques, Gear boxes, Gear teeth, Failure detection, Fatigue life

Excitation of low frequency vibration in gear systems by impacts arising from gear tooth defects is examined. It is demonstrated that in favorable conditions the low frequency vibration can be isolated and used to monitor the condition of the gear.

86-1139
The Local Method of Free Elastic Vibrations and its Applications to Testing in Industry
Yu. V. Lange
Scientific Res. Inst. of Introscopy, Moscow, USSR
NDT Intl., 18 (5), pp 256-260 (Oct 1985) 3 figs, 32 refs

KEY WORDS: Nondestructive tests, Layered materials, Acoustic tests, Failure detection

The local method of free vibrations and its physical basis are considered. Results of investigations of pulse impact vibration parameters, the transformation of their spectra arising from the probe interaction with the test object, and receiver frequency response to elastic vibrations are considered. The test equipment, its characteristics and application, are briefly described. Examples of the use of this method in different fields of industry are given. The advantages of the method in comparison with other low-frequency acoustic NDT methods of considerable depth of detected flaws and the possibility for testing materials with low Young's modulus and high damping factors.

86-1140
Application of a Signal Reconstruction Method to Evaluate Pulsed Eddy-Current Signals
H.-M. Thomas, G. Wittig
Federal Inst. for Materials Testing, Berlin, Fed. Rep. Germany
NDT Intl., 18 (5), pp 251-255 (Oct 1985) 8 figs, 7 refs

KEY WORDS: Signal processing techniques, Eddy current probes, Failure detection

To evaluate subsurface material defects, a digital signal processing system has been developed that is matched to the particular requirements of pulsed eddy-current techniques. The signal processing is designed to obtain information about defect depth within thick components of the residual wall thickness of corroded tubes or austenitic container walls. It is found that it is possible to reconstruct the pulse response signal from 8 to 10 sampled and stored amplitude values. The zero-crossing point of the signal, which is a measure of the defect depth, is relatively simple to determine from an analytical function.

86-1141
Experimental and Theoretical Assessment of a New Technique for the Non-Destructive Evaluation of Laminated Panels
V.H. Kenner
Ohio State Univ., Columbus, OH
Rept. No. AFWAL-TR-84-4129, 90 pp (Feb 21, 1985) AD-A155 622/4/GAR

KEY WORDS: Crack detection, Panels, Layered materials

The goal of the present research project was to evaluate a potential method of edge flaw detection in laminated structures. This method used miniature dynamic force transducers to detect the changes in loading history arising from the (very low level) impact of steel spheres on the transducer, which is located on the surface of the examined object.

86-1142
Determination of Minimum Flaw Size Detectable by Ultrasonics in Titanium Alloy Plates
N.K. Batra, H.H. Chaskelis
Naval Res. Lab., Washington, DC
NDT Intl., 18 (5), pp 261-264 (Oct 1985) 6 figs, 3 refs

KEY WORDS: Crack detection, Titanium, Ultrasonic techniques

Titanium alloys, due to their light weight, high strength, and corrosion resistant properties, are employed in many structural applications. For design purposes it is important to determine the limit of sensitivity of ultrasonic crack detection techniques for these alloys. This paper demonstrates that it it possible to detect electronic discharge mill (EDM) slots as small as 0.025 mm deep in thick plates, using commercial ultrasonic instrumentation. The effect of grain size, frequency and orientation of the flaw upon the limit of detection is also discussed.

MONITORING

86-1143
Challenges in Predictive Maintenance
R.L. Eshleman
Vibration Institute, Clarendon Hills, IL
Vibrations, 1 (2), pp 2-4 (Sept 1985) 2 figs, 2 refs

KEY WORDS: Monitoring techniques

This article explores some of the challenges that must be met if predictive maintenance is to be functional and cost effective. Techniques for diagnosis, predictions of response, and life estimation, now in early stages of development, must be refined. Major challenges are to develop models that describe response, conditions, and failure as well as procedures that provide life estimates of machine components and systems.

ANALYSIS AND DESIGN

ANALYTICAL METHODS

86-1144
Transient Loads Analysis by Dynamic Condensation
K. Kubomura
Beloit Manhattan, Clarks Summit, PA
J. Appl. Mech., Trans. ASME, 52 (3), pp 559-564 (Sept 1985) 3 figs, 18 refs

KEY WORDS: Finite difference technique, Time integration method, Transient excitation

This paper investigates on alternative finite-difference time-integration procedure in structural dynamics. The integral form of the equation of motion, instead of the differential form, is used to develop the finite-difference time-integration method. An expression called dynamic con-

densations is presented to relate the dynamic response and unknown force at a limited number of degrees of freedom. A stable and accurate method of analysis is derived to determine the transient loads of structural components in a structural system without constructing the system equation of motion.

86-1145

On the Recursive Determination of Body Frames for Multibody Dynamic Simulation

R.E. Roberson

Univ. of California San Diego, La Jolla, CA

J. Appl. Mech., Trans. ASME, 52 (3), pp 698-700 (Sept 1985) 4 refs

KEY WORDS: Multibody systems, Simulation

In multibody dynamic simulation it often is convenient to choose new body axes such that all body frames are parallel to the attitude reference frame when the system of bodies is in a prescribed configuration consistent with the interbody constraints. Computational details are given of how this may be done efficiently using a recursive method.

86-1146

Constitutive Model for Concrete in Cyclic Compression

Chen En-Sheng, O. Buyukozturk

Brian Watt Associates, Houston, TX

ASCE J. Engrg. Mech., 111 (6), pp 797-814 (June 1985) 8 figs, 41 refs

KEY WORDS: Concrete, Cyclic loading, Constitutive equations, Finite element technique

A rate-independent constitutive model is proposed for the behavior of concrete in multiaxial cyclic compression. The material composite is assumed to experience a continuous damage process under load histories. The model adopts a damage-dependent bounding surface in stress space to predict the strength and deformation characteristics of the gross material under general loading paths. Reduction in size of the bounding surface as damage accumulates, and the adopted functional dependence of the material moduli on stress and damage permit a realistic modeling of the concrete behavior. Finite element implementation of the proposed model is feasible and computationally efficient.

86-1147

The Response of Non-Linear Single-Degree-of-Freedom Systems to Multifrequency Excitations

A.H. Nayfeh

Virginia Polytechnic Institute and State University, Blacksburg, VA

J. Sound Vib., 102 (3), pp 403-414 (Oct 8, 1985) 4 figs, 23 refs

KEY WORDS: Single degree of freedom systems, Multifrequency excitation

The method of multiple scales is used to analyze the response of single-degree-of-freedom systems with cubic non-linearities to excitations that involve multiple frequencies. Two first-order ordinary differential equations are derived for the evolution of the amplitude and phase with damping, nonlinearity, and all possible resonances. Conditions for the existence and stability of steady-state solutions are determined. These results are used to suggest simple means of controlling or minimizing the large oscillations. These means may take the form of adding non-resonant loads that shift the natural frequency of the system or adding another resonant load having the proper frequencies, amplitudes and phases.

86-1148

Operators and Fractional Derivatives for Viscoelastic Constitutive Equations

L. Rogers

Air Force Wright Aeronautical Labs., Wright-Patterson Air Force Base, OH

(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp B-6 -B-16, AD-A152 547) AD-P004 688/8/GAR

KEY WORDS: Complex modulus, Constitutive equations, Viscoelasticity

The operator form of the constitutive equation containing fractional derivatives leads to an expression for the complex modulus which is a ratio of polynomials of fractional order in reduced frequency. A ration of factored polynomials is developed by use of Bode diagrams; another related form arises from the generalized fractional Maxwell model. Bode diagrams are used to determine parameter values. Interconversion to other mechanical properties is outlined. The results potentially form the basis of new theory.

86-1149

New Algorithm for Interconversion of the Mechanical Properties of Viscoelastic Materials

L. Rogers

Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, pp B-17 -B-22, AD-A152 547) (Presented AIAA Dyn. Specialists Conf., Palm Springs, CA, May 17-18, 1984, Paper No. 84-1038-CP) AD-P004 689/6/GAR

KEY WORDS: Viscoelastic properties, Complex modulus

The new algorithm presented consists of the use of a ratio of factored polynomials in the reduced frequency to approximate the complex modulus and an artful procedure to evaluate the parameters. A corresponding Prony series is easily obtained to represent the relaxation modulus; the creep compliance and discrete relaxation and retardation spectra are likewise easily obtained. Series representations with 50 terms are routinely used; they are very convenient and well-behaved.

86-1150
Resolution Bias Errors in Spectral Density, Frequency Response and Coherence Function Measurements, I: General Theory
H. Schmidt
Abt. EMA, Daimler-Benz Aktiengesellschaft, Stuttgart, Fed. Rep. Germany
J. Sound Vib., 101 (3), pp 347-362 (Aug 8, 1985) 4 figs, 19 refs

KEY WORDS: Error analysis, Power spectral density, Frequency response, Coherence function technique, Measurement techniques

A general theory of resolution bias errors inherent in the usual ensemble (segment) averaging estimation procedure for spectral density, frequency response and coherence functions has been developed. It is shown that the estimation procedure is mathematically equivalent to a situation where the true correlation functions would be modified in a specific manner. They would be multiplied with the normalized autocorrelation function of the window function and transformed into the frequency domain to yield the spectral density estimate. The theory is worked out for an arbitrary ideal, linear, and time-invariant system which is driven by a stationary stochastic input and for an arbitrary window function. Specifically, the rectangular and Hanning windows are compared with each other and the theoretical results are verified experimentally to great accuracy by using electrical RC- and LRC-circuits and a true random noise generator (see later parts of this series of papers). Furthermore, as an application of the theory, approximate formulas for the bias errors of spectral estimators are derived and discussed, thus extending some older results given in the literature.

86-1151
Resolution Bias Errors in Spectral Density, Frequency Response and Coherence Function Measurements, II: Application to First-Order Systems (White Noise Excitation)
H. Schmidt
Abt. EMA, Daimler-Benz Aktiengesellschaft, Stuttgart, Fed. Rep. Germany
J. Sound Vib., 101 (3), pp 363-375 (Aug 8, 1985) 11 figs, 5 refs

KEY WORDS: Error analysis, Power spectral density, Frequency response, Coherence function technique, Measurement techniques

A general theory of spectral estimation presented in a preceding paper is applied to first-order systems such as an electrical RC-low-pass filter and an RC-high-pass filter. By means of bias error formulas which are easy to interpret, the results for the rectangular and Hanning windows are compared with each other. The theoretical predictions are accurately verified by experiment.

86-1152
Resolution Bias Errors in Spectral Density, Frequency Response and Coherence Function Measurements, III: Application to Second-Order Systems (White Noise Excitation
H. Schmidt
Abt. EMA, Daimler-Benz Aktiengesellschaft, Stuttgart, Fed. Rep. Germany
J. Sound Vib., 101 (3), pp 377-404 (Aug 8, 1985) 24 figs, 6 refs

KEY WORDS: Error analysis, Power spectral density, Frequency response, Coherence function technique, Measurement techniques

A general theory of spectral estimation given in a previous paper is applied to second-order systems such as a simple spring-mass system where either the displacement, velocity, or acceleration of the vibrating mass may be considered as the output signals. By means of approximate formulas, an extensive bias error discussion of frequency response, output power

spectral density and coherence estimates is given. All of the theoretical predictions are verified experimentally to great accuracy by using electrical LRC resonance circuits which are equivalent to the respective mechanical systems.

86-1153

Resolution Bias Errors in Spectral Density, Frequency Response and Coherence Function Measurements, IV: Time Delay Bias Errors

H. Schmidt
Abt. EMA, Daimler-Benz Aktiengesellschaft, Stuttgart, Fed. Rep. Germany

J. Sound Vib., 101 (3), pp 405-412 (Aug 8, 1985)
7 figs, 1 table 7 refs

KEY WORDS: Error analysis, Power spectral density, Frequency response, Coherence function technique, Measurement techniques

The problem of time delay bias errors is treated in this part of the present series of papers as a special case of a general theory of resolution bias efforts in spectral estimation presented in a previous part. It is shown that the main effect of an additional time delay between the output and the input of a physical system is to multiply the frequency response and coherence estimators. They are obtained without delay with the normalized autocorrelation function of the window function and its square respectively. Experimental results for the rectangular and Hanning windows are in accord with the theoretical predictions. The theoretical results given in the literature previously are valid for the rectangular window only but not for an arbitrary window function.

86-1154

Resolution Bias Errors in Spectral Density, Frequency Response and Coherence Function Measurements, V: Comparison of Different Frequency Response Estimators

H. Schmidt
Abt. EMA, Daimler-Benz Aktiengesellschaft, Stuttgart, Fed. Rep. Germany

J. Sound Vib., 101 (3), pp 413-418 (Aug 8, 1985)
1 fig, 8 refs

KEY WORDS: Error analysis, Power spectral density, Frequency response, Coherence function technique, Measurement techniques

Three different types of frequency response estimators are considered and compared with each other. The inherent resolution bias errors are considered. The behavior of these estimators is shown to differ considerably, especially with respect to peak estimation in resonance systems such as a simple spring-mass system. One of these estimators is shown to exhibit almost no peak bias error at resonance under noise-free measurement conditions whereas the peak bias error of the estimator most commonly used is maximum. However, aside from resonance, the peak-bias-free estimator proves to be the worst of the three estimators. The theoretical predictions are accurately verified by experiments with an electrical LRC-resonance circuit.

86-1155

Resolution Bias Errors in Spectral Density, Frequency Response and Coherence Function Measurements, VI: Non-White Noise at the Input

H. Schmidt
Abt. EMA, Daimler-Benz Aktiengesellschaft, Stuttgart, Fed. Rep. Germany

J. Sound Vib., 101 (3), pp 419-427 (Aug 8, 1985)
4 figs, 7 refs

KEY WORDS: Error analysis, Power spectral density, Frequency response, Coherence function technique, Measurement techniques

The general theory of spectral estimation presented in a previous part of this series of papers is applied exemplarily to the case of a non-white $(1/f^2)$-noise excited RC-low-pass filter. It is shown that the differences compared to the case of white noise excitation observed in the frequency response and coherence estimates are small if the Hanning (or another continuous) window is used, but that they can become drastic for the rectangular window. Experimental results are in accord with the theoretical prediction. Further experiments with an electrical LRC-resonance circuit (second-order system) show that the same applies in this case.

PARAMETER IDENTIFICATION

86-1156

Stiffness Matrix Adjustment Using Mode Data

A.M. Kabe

Aerospace Corp., El Segundo, CA
AIAA J., 23 (9), pp 1431-1436 (Sept 1985) 1 fig, 5 tables, 17 refs

KEY WORDS: Stiffness matrices, Parameter identification techniques

A procedure is introduced that uses, in addition to mode data, structural connectivity information to optimally adjust deficient stiffness matrices. The adjustments performed are such that the percentage change to each stiffness coefficient is minimized. The physical configuration of the analytical model is preserved and the adjusted model will exactly reproduce the modes used in the identification. The theoretical development is presented and the procedure is demonstrated by numerical simulation of a test problem.

AUTHOR INDEX

TECHNICAL NOTES

N.A. Halliwell and P.G. Eastwood
The Laser Torsional Vibrometer
J. Sound Vib., 101 (3), pp 446-449 (Aug 8, 1985)
3 figs, 1 ref

W.T. Chu
Single-Microphone Method for Certain Applications of the Sound Intensity Technique
J. Sound Vib., 101 (3), pp 443-445 (Aug 8, 1985)
1 table, 8 refs

P.A.A. Laura, R.O. Grossi, L. Ercoli and E. Goldfracht
Dynamic Analysis of Machine-Supporting Non-Uniform Plates
J. Sound Vib., 101 (4), pp 585-588 (Aug 22, 1985) 1 fig, 2 tables, 2 refs

N. Ganesan and S.N. Rao
Influence of Location of Cut-Outs on Natural Frequencies of Thin Square Plates
J. Sound Vib., 101 (4), pp 598-600 (Aug 22, 1985) 2 figs, 2 tables, 6 refs

T. Nakao, T. Okano, and I. Asano
Theoretical and Experimental Analysis of Flexural Vibration of the Viscoelastic Timoshenko Beam
J. Appl. Mech., Trans. ASME, 52 (3), pp 728-731 (Sept 1985) 3 figs, 1 table, 10 refs

T. Irie and Y. Kobayashi
Steady-State Response of an Internally Damped Cylindrical Shell Translationally or Rotationally Driven at an Edge
J. Appl. Mech., Trans. ASME, 52 (3), pp 733-736 (Sept 1985) 5 figs, 6 refs

R. Craik and G. Naylor
Measurement of Reverberation Time Via Probability Functions
J. Sound Vib., 102 (3), pp 453-454 (Oct 8, 1985)
2 figs

T. Sakiyama
Free Vibrations of Arches with Variable Cross Section and Non-Symmetrical Axis
J. Sound Vib., 102 (3), pp 448-452 (Oct 8, 1985)
3 figs, 3 tables, 10 refs

J.C. Utjes, L. Ercoli, P.A.A. Laura, and R.D. Santos
Transverse Vibrations of Right Triangular Plates Having the Hypotenuse Free
J. Sound Vib., 102 (3), pp 445-447 (Oct 8, 1985)
1 fig, 1 table, 3 refs

B.P. Shastry and G.V. Rao
Free Vibrations of Short Unconstrained Beams
J. Sound Vib., 102 (3), pp 442-444 (Oct 8, 1985)
4 tables, 4 refs

T. Kapitaniak
Stochastic Response with Bifurcations to Non-Linear Duffing's Oscillator
J. Sound Vib., 102 (3), pp 440-441 (Oct 8, 1985)
1 fig, 4 refs

D.J. Gunaratnam and A.P. Bhattacharya
Transverse Vibration of Circular Plates Having Mixed Elastic Rotational Edge Restraints and Subject to In-Plane Forces
J. Sound Vib., 102 (3), pp 431-439 (Oct 8, 1985)
4 figs, 5 tables, 14 refs

Ki-Ook Kim
Dynamic Condensation for Structural Redesign
AIAA J., 23 (11), pp 1830-1832 (Nov 1985) 4 tables, 6 refs

C.S. Kim and S.M. Dickinson
Improved Approximate Expressions for the Natural Frequencies of Isotropic and Orthotropic Rectangular Plates
J. Sound Vib., 103 (1), pp 142-149 (Nov 8, 1985)
4 tables, 8 refs

CALENDAR

JUNE

3-6 Symposium and Exhibit on Noise Control [Hungarian Optical, Acoustical, and Cinematographic Society; National Environmental Protection Authority of Hungary] Szeged, Hungary (Mrs. Ildiko Baba, OPAKFI, Anker koz 1, 1061 Budapest, Hungary)

8-12 Symposium on Dynamic Behavior of Composite Materials, Components and Structures [Society for Experimental Mechanics] New Orleans, LA (R.F. Gibson, Mech. Engrg. Dept., University of Idaho, Moscow, ID 83843 - (208) 885-7432)

24-26 Machinery Vibration Monitoring and Analysis Meeting [Vibration Institute] Las Vegas, NV (Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254)

JULY

14-16 Intersociety Environments Systems [SAE], San Diego, CA (412-776-4841)

20-24 Pressure Vessels and Piping Conference and Exhibition [ASME, concurrent with International Computers in Engin.ering Conference and Exhibit], Chicago, IL (212-705-7057)

20-24 International Computers in Engineering Conference and Exhibition [ASME] Chicago, IL (ASME)

21-23 INTER-NOISE 86 [Institute of Noise Control Engineering] Cambridge, MA (Professor Richard H. Lyon, Chairman, INTER-NOISE 86, INTER-NOISE 86 Secretariat, MIT Special Events Office, Room 7-111, Cambridge, MA 02139)

24-31 12th International Congress on Acoustics, Toronto, Canada (12th ICA Secretariat, P.O. Box 123, Station Q, Toronto, Ontario, Canada M4T 2L7)

SEPTEMBER

14-17 International Conference on Rotordynamics [IFToMM and Japan Society of Mechanical Engineers] Tokyo, Japan (Japan Society of Mechanical Engineers, Sanshin Hokusei Bldg., 4-9, Yoyogi 2-chome, Shibuyak-ku, Tokyo, Japan)

16-18 Fall National Design Engineering Conference and Show (Cahners Exposition Group, New York, NY 203-964-0000)

21-23 Petroleum Workshop and Conference, Calgary, Canada (214-358-7601)

22-25 World Congress on Computational Mechanics [International Association of Computational Mechanics] Austin, Texas (WCCM/TICOM, The University of Texas at Austin, Austin, TX 78712)

29-30 VDI Vibrations Meeting [Society of German Engineers] Wurzburg, Fed. Rep. Germany (Society of German Engineers)

30-3 6th International Conference on Nondestructive Testing, Strasbourg, France (M.P. Pomes, 25 rue de Chong, 26500 Bourg les Valence, France)

OCTOBER

5-8 Design Automation Conference [ASME] Columbus, OH (ASME)

5-8 **Mechanisms Conference** [ASME] Columbus, OH (ASME)

7-9 **2nd International Symposium on Shipboard Acoustics ISSA '86** [Institute of Applied Physics TNO] The Hague, The Netherlands (J. Buiten, Institute of Applied Physics TNO, P.O. Box 155, 2600 AD Delft, The Netherlands, Telephone: xx31 15787053, Telex: 38091 tpddt nl)

14-16 **57th Shock and Vibration Symposium** [Shock and Vibration Information Center] New Orleans, LA (Dr. J. Gordan Showalter, Acting Director, SVIC, Naval Research Lab., Code 5804, Washington, D.C. 20375-5000 - (202) 767-2220)

19-23 **Power Generation Conference** [ASME] Portland, OR (ASME)

20-22 **Lubrication Conference** [ASME] Pittsburgh, PA (ASME)

NOVEMBER

3-6 **14th Space Simulation Conference** [IES, AIAA, ASTM, NASA] Baltimore, MD (Institute of Environmental Sciences, 940 E. Northwest Highway, Mt. Prospect, IL 60056 - (312) 255-1561)

7-14 **Turbomachinery Symposium**, Corpus Christi, TX (Turbomachinery Laboratories, Dept. of Mech. Engrg., Texas A & M Univ., College Station, TX 77843)

30-5 **American Society of Mechanical Engineers, Winter Annual Meeting** [ASME] San Francisco, CA (ASME)

DECEMBER

7-12 **ASME Winter Annual Meeting**, Anaheim, CA (ASME, United Engrg. Center, 345 East 45th Street, New York, NY 10017)

8-12 **ASA**, Anaheim, CA (Joie P. Jones, Dept. Radiology Sciences, Univ. of California, Irvine, CA 92717)

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AHS	American Helicopter Society 1325 18 St. N.W. Washington, D.C. 20036
AIAA	American Institute of Aeronautics and Astronautics 1633 Broadway New York, NY 10019
ASA	Acoustical Society of America 335 E. 45th St. New York, NY 10017
ASCE	American Society of Civil Engineers United Engineering Center 345 E. 47th St. New York, NY 10017
ASLE	American Society of Lubrication Engineers 838 Busse Highway Park Ridge, IL 60068
ASME	American Society of Mechanical Engineers United Engineering Center 345 E. 47th St. New York, NY 10017
ASTM	American Society for Testing and Materials 1916 Race St. Philadelphia, PA 19103
ICF	International Congress on Fracture Tohoku University Sendai, Japan
IEEE	Institute of Electrical and Electronics Engineers United Engineering Center 345 E. 47th St. New York, NY 10017
IES	Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056
IMechE	Institution of Mechanical Engineers 1 Birdcage Walk, Westminster London SW1, UK
IFToMM	International Federation for Theory of Machines and Mechanisms U.S. Council for TMM c/o Univ. Mass., Dept. ME Amherst, MA 01002
INCE	Institute of Noise Control Engineering P.O. Box 3206, Arlington Branch Poughkeepsie, NY 12603
ISA	Instrument Society of America 67 Alexander Dr. Research Triangle Pk., NC 27709
SAE	Society of Automotive Engineers 400 Commonwealth Dr. Warrendale, PA 15096
SEE	Society of Environmental Engineers Owles Hall, Buntingford, Hertz. SG9 9PL, England
SESA	Society for Experimental Mechanics (formerly Society for Experimental Stress Analysis) 14 Fairfield Dr. Brookfield Center, CT 06805
SNAME	Society of Naval Architects and Marine Engineers 74 Trinity Pl. New York, NY 10006
SPE	Society of Petroleum Engineers 6200 N. Central Expressway Dallas, TX 75206
SVIC	Shock and Vibration Information Center Naval Research Laboratory Code 5804 Washington, D.C. 20375-5000

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PUBLICATION POLICY

Unsolicited articles are accepted for publication in the **Shock and Vibration Digest.** Feature articles should be tutorials and/or reviews of areas of interest to shock and vibration engineers. Literature review articles should provide a subjective critique/summary of papers, patents, proceedings, and reports of a pertinent topic in the shock and vibration field. A literature review should stress important recent technology. Only pertinent literature should be cited. Illustrations are encouraged. Detailed mathematical derivations are discouraged; rather, simple formulas representing results should be used. When complex formulas cannot be avoided, a functional form should be used so that readers will understand the interaction between parameters and variables.

Manuscripts must be typed (double-spaced) and figures attached. It is strongly recommended that line figures be rendered in ink or heavy pencil and neatly labeled. Photographs must be unscreened glossy black and white prints. The format for references shown in **Digest** articles is to be followed.

Manuscripts must begin with a brief abstract, or summary. Only material referred to in the text should be included in the list of References at the end of the article. References should be cited in text by consecutive numbers in brackets, as in the following example:

> Unfortunately, such information is often unreliable, particularly statistical data pertinent to a reliability assessment, as has been previously noted [1].
>
> Critical and certain related excitations were first applied to the problem of assessing system reliability almost a decade ago [2]. Since then, the variations that have been developed and practical applications that have been explored [3-7] indicate . . .

The format and style for the list of References at the end of the article are as follows:

-- each citation number as it appears in text (not in alphabetical order)
-- last name of author/editor followed by initials or first name
-- titles of articles within quotations, titles of books underlined
-- abbreviated title of journal in which article was published (see Periodicals Scanned list in January, June, and December issues)
-- volume, issue number, and pages for journals; publisher for books
-- year of publication in parentheses

A sample reference list is given below.

1. Platzer, M.F., "Transonic Blade Flutter -- A Survey," Shock Vib. Dig., 7 (7), pp 97-106 (July 1975).

2. Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., Aeroelasticity, Addison-Wesley (1955).

3. Jones, W.P., (Ed.), "Manual on Aeroelasticity," Part II, Aerodynamic Aspects, Advisory Group Aeronaut. Res. Dev. (1962).

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Milda Z. Tamulionis
Research Editor
Vibration Institute
101 W. 55th Street, Suite 206
Clarendon Hills, Illinois 60514

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Partial contents:

EDITORIAL

ARTICLES AND REVIEWS

CURRENT NEWS

ABSTRACTS FROM THE CURRENT LITERATURE

CALENDAR